CANADA-BRITISH COLUMBIA PARTNERSHIP AGREEMENT ON FOREST RESOURCE DEVELOPMENT: FRDA II

Canada

BC

BACKGROUND AND RECOMMENDATIONS FOR JUVENILE SPACING STANDARDS IN B.C.

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May 1992

106-01014/

Funding for this publication was provided by
the Canada - British Columbia Partnership Agreement on
Forest Resource Development: FRDA II -
a four year (1991-95) $200 million program cost-shared equally by
the federal and provincial governments.

ACKNOWLEDGEMENTS

A number of individuals contributed significantly to the preparation of this document. In particular we would like to thank:

- Gary Townsend, Economics and Trade Branch (MoF)
- Frank Barber, Mike Wyeth, and Ralph Winter, Silviculture Branch (MoF)
- Gary Lloyd and Lou Tromp, Silviculture Section, Prince Rupert Forest Region (MoF)
- Mike Connor and Les Herring, Silviculture Section, Prince George Forest Region (MoF)
- Al Randall, Silviculture Section, Cariboo Forest Region (MoF)
- Yo Yano and Alan Vyse, Silviculture and Research Sections respectively, Kamloops Forest Region (MoF)
- Bob Johnson and Jim Wright from the Salmon Arm Forest District, Kamloops Forest Region (MoF)
- Gerry Reichenbach, Bernie Peschke, and Ivan Listar, Silviculture Section, Nelson Forest Region (MoF)
- Ted Nash, Kevin Carvill, Mel Scott and Hal Reveley, Silviculture Section, Vancouver Forest Region (MoF)
- Les Jozsa of Forintek
- Jim Thrower of J.S. Thrower & Associates Ltd. and
- Dave Handley formerly of MacMillan Bloedel Ltd., now retired

Our special thanks as well to Ken Mitchell and Ken Polsson from the Forest Productivity and Decision Support Section, Research Branch (MoF), for their valuable time conducting required TASS runs and providing critical feedback on procedures.

Finally, we would also like to acknowledge Gary Townsend, Ken Mitchell, Frank Barber, Kevin Carvill, Dave Handley, Les Jozsa, Ian Moss, Jane Lloyd-Smith, Tim Ebata, and Don Heppner for their respective editorial reviews.

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1.0 INTRODUCTION

1.1 Background

With the continual decline in the provincial forest land base and AAC shortfalls forecast for some areas of the province, there has been renewed interest in the potential to mitigate these problems through incremental silviculture. This concern has been reflected in target expenditures for juvenile spacing, forecast to be $120 million for the period 1992-1995. [1.]

Previous guidelines on spacing (Provincial Guidelines for Establishing Stand Tending Projects, 1979) do not provide a sufficiently rigorous framework to ensure that budgets are spent in the most effective manner possible. This document, prepared under contract, represents an updated approach based on managed stand yield tables and financial analysis.

1.2 Scope and Objectives

The purpose of the document is to provide juvenile spacing guidelines which can be used at the District/Divisional level to:

- determine whether spacing is financially attractive,
- establish relative priorities amongst candidate stands,
- determine appropriate treatment densities and rotations.

The above information is presented in tabular format to facilitate its use as an operational tool. The accompanying text is provided to help operations staff understand ***some*** of the principles of density management, factors affecting the decision to space, and limitations of the guidelines.

It is important to note that this document is based on ***stand level*** analysis. Factors such as job creation and social welfare, which are best addressed at a higher planning level, and factors such as pest impacts and biodiversity, for which little yield data exist, have not been directly incorporated in the tables. Such factors have been discussed in conceptual terms, however, since they can have an important bearing on the decision to juvenile space.

Species directly addressed in these guidelines include coastal Douglas-fir (Fdc), coastal western hemlock (Hwc), interior wetbelt Douglas-fir (Fdi), interior western hemlock (Hwi), interior lodgepole pine (Pl), and interior spruce (Sx). Guidelines for drybelt interior Douglas-fir (uneven-aged stands) and Sitka spruce may be provided at a later date in an addendum. All other species will simply be equated to one of the principal species listed above.

2.0 PRINCIPLES OF DENSITY MANAGEMENT

These guidelines are a tool to help forest planners make appropriate decisions about juvenile spacing. They are meant to be a guide only and too literal an interpretation or stringent adherence to details may result in a treatment which is inappropriate for local circumstances. Conversely, any deviation from the guidelines should be based on accepted forest management practices and sound economic rationale. In this section we have, therefore, provided some of the more pertinent background on density management as it applies to growth and yield. The primary objective is to help the user understand the consequences of spacing decisions.

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1. Includes funding from both the FRDA program and the provincial program.

2.1 Tree and Stand Growth

2.1.1 Growth Factors

Tree growth is a function of available sunlight, water, nutrients, oxygen, and carbon dioxide (Smith 1962, Oliver and Larson 1990). Juvenile spacing changes the availability of these factors and a successful spacing program will recognize 3 basic principles governing the relationship between supply and growth.

1. *Balanced Supply.*
   There must be a balanced supply of all growth factors. If even one factor becomes limiting, tree growth will be less than the potential maximum. Increasing the light available to individual trees through spacing, for example, may not result in increased growth on very poor or dry sites since water or nutrients may be limiting.

2. *Threshold Levels.*
   In some circumstances, there is a minimum level of factor required before growth can occur. Oliver and Larson (1990) report, for example, that the lowest light intensity at which a leaf can sustain itself (known as the compensation point) ranges from 0.3 to 1.5 percent of full sunlight for most woody plants. More light is necessary for whole trees to survive since the leaves must support branches, boles, and roots as well. The minimum level for survival of white spruce seedlings in B.C., for example, appears to range from 2 - 10% of full sunlight (Binder *et al.* 1987).

3. *Level of Maximum Utilization.*
   There is also a maximum level beyond which further inputs of growth factor do not result in more growth. Using light again as an example, Lavender (1990) states that, under laboratory conditions, photosynthesis in forest trees is normally saturated at approximately 40% of full sunlight. Under natural conditions, however, because of shading of foliage by adjacent branches, some species require light levels as high as 75% of full sunlight for optimum growth.

Juvenile spacing, then, should be used as a tool to control the rate of supply and distribution of growth factors to crop trees. Reducing density opens the canopy increasing light, reducing snow interception and transpirational losses, and improving soil temperature and nutrient cycling (Debell 1981). Ultimately the goal is to control inter-tree spacing such that the supply of limited site resources results in maximum volume and diameter growth.

2.1.2 Allocation of Growth Factors

Growth is a result of photosynthesis and respiration processes made possible by the assimilation of growth factors (sunlight, water, nutrients, oxygen, and carbon dioxide). The products of photosynthesis (photosynthates) are used to build structural and functional components of trees and to provide energy for respiration. Photosynthate production must exceed photosynthate use during respiration or no growth will occur and at some point the tree will die. This occurs where excessively small crowns (source of photosynthates), resulting from crown competition within a dense stand, are too small to support respirational demands from living cells in the foliage, branches, bole, and roots.

Any excess photosynthate beyond respirational needs is allocated to growth. Mar - Moller *et al.* (1954, cited by Weetman 1978) show how photosynthates may be allocated in a stand of European beech.

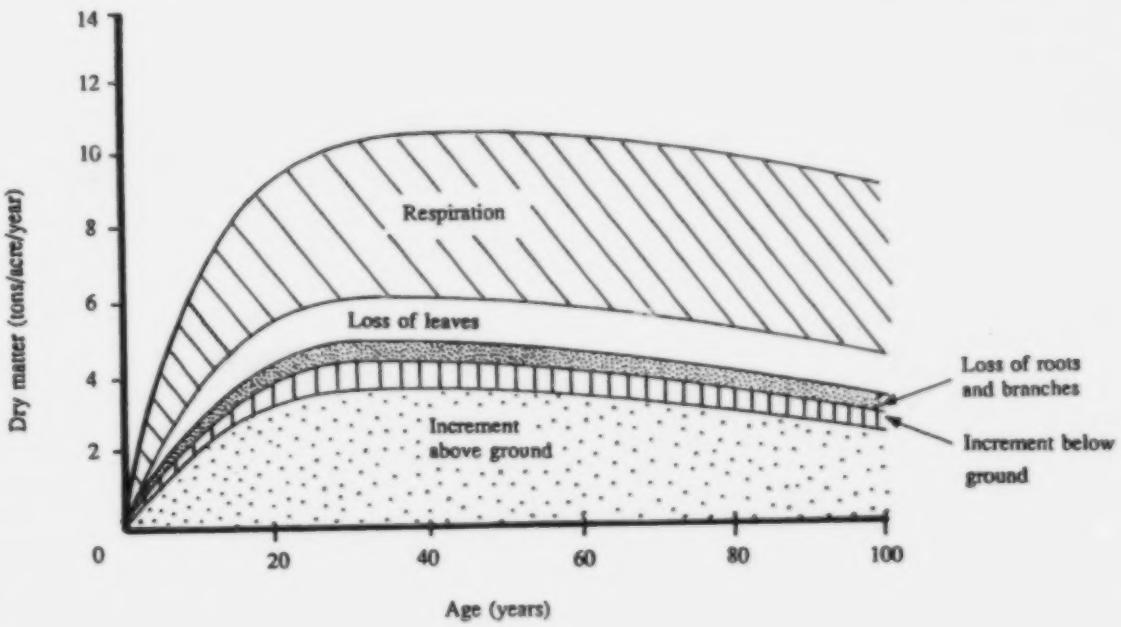

FIGURE 1. The allocation of carbohydrates in an even-aged stand of European beech during the course of about one rotation.

Allocation changes from site to site and with age but, in general, photosynthates are allocated in a specific order as follows (Oliver and Larson 1990):

1 - maintenance of respiring tissue
2 - production of new leaves and fine roots
3 - production of flowers and seed
4 - terminal and lateral branch and root extension
5 - diameter growth and resistance to pests

When competition for limited resources occurs, diameter growth is the first thing to be affected.

2.1.3 Measuring Growth

Growth is most commonly expressed as height, diameter, or volume increment or dry matter weight increases over a period of time. A convenient way of describing growth is the height/age curve. The advantage of this type of curve is that it integrates the effects of all growth factors into a single index often referred to as site index. Site index is defined as the average height of dominant trees in an even-aged, adequately stocked stand at a specified age, generally 50 years at breast height (Thrower 1989). Site index is the best measure of site quality since, unlike diameter or volume, it is relatively independent of the degree of stand crowding over a wide range of densities (Thrower 1989, Goudie 1980, and Oliver and Larson 1990). Note that only *dominant* trees are used to measure site index because it is less likely that height growth of these trees will have been affected by overhead shade.

2.1.4 Diameter and Height Growth in Relation to Site Quality

Height and diameter growth both improve with increasing site quality. TASS (1992) simulations conducted during preparation of this report show that substantial increases in average stand diameter occur at a given age on better sites.

TABLE 1. Average stand diameter at breast height at 90 years when initial density was 1600 stems/ha (naturally established) and the stand was not thinned. (Source: TIPSY Ver. 2.0b 1991).

	Site Index				
Species	10	15	20	25	30
Pl	15.0	21.1	27.6	-	-
Sw	13.3	20.6	27.1	33.7	40.5
Hwc	12.9	20.5	27.6	34.4	42.9
Fdc	10.9	17.9	24.1	30.8	38.4

Height growth also increases on better sites and, within a wide range of densities, is highly correlated with site quality. It should be noted, however, that stands of similar height and density will have a similar *yield* regardless of site quality (Goudie *et al.* 1990). On a poor site it will simply take longer to achieve a given height and yield than on a good site (i.e. *growth* rate is different). Stand structure, therefore, is often discussed relative to the height of dominant trees in a stand (referred to as site height) rather than age. Using site height allows stand structure and yield to be stated without having to refer to site quality.

2.2 The Impact of Stand Density on Crown Development and Growth

Crown development, and ultimately diameter and height growth of individual trees, is also affected by stand density. Density is the degree of crowding within a stand and is described with variables such as stems/ha, basal area/ha, or volume/ha (Husch *et al.* 1972). Stocking, in contrast, is the proportion of an area actually occupied by trees (how much of the site is being used by trees).

2.2.1 Density and Crown Development

As individual trees grow their crowns expand asymmetrically in response to the availability of growth factors, physical restrictions, pests, and management activities. A shell of new foliage is added to the tree every year with sun leaves on the outside and shade leaves produced at points inside the shell. Farther inside the shell living leaves are not found (Oliver and Larson 1990). As conifer leaves age they become progressively less efficient and after a few years die and fall off. Leaf mortality is advanced with increasing shade and if sufficient mortality occurs, death of the entire branch will occur.

When trees first establish on a site, growth is not restricted by competition from other trees and crown volume increases until crowns begin to overlap. At this point, increased shading of lower branches will eventually lead to their death and crown size will remain relatively constant unless differentiation occurs. Oliver and Larson (1990) have depicted this graphically using the concept of a circular wall around the tree.

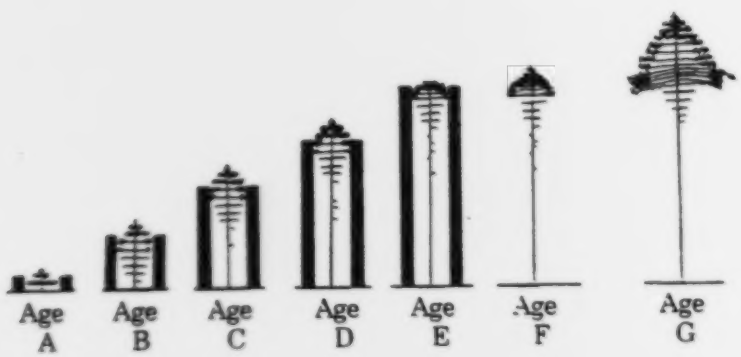

FIGURE 2. Crown development of an individual tree surrounded by a wall. Note that at age F the tree was released (wall removed) and crown enlargement occurred.

Crown closure and recession of the crown, then, are a consequence of intertree competition for growing space. If crown size remains constant, the tree will eventually grow tall enough that respirational needs will exceed photosynthate production, diameter and finally height growth will slow, and eventually the tree will die. In most stands, however, there are several factors which result in differentiation between trees. These include stem spacing, microsite differences, genetics, stem age, species, and pests (Oliver 1990). As certain trees dominate through differentiation, they *suppress* their neighbors and may cause mortality. Differentiation does not, however, mean that maximum growth will occur since competition for growth factors still exists.

2.2.2 Repression

Repression occurs in relatively uniform stands where height growth reduction is suffered by all trees. When reduced height and diameter growth is suffered by only those trees that cannot compete effectively for growing space, it is known as suppression (Mitchell, pers. comm. 1992). There has been speculation that, at very high densities, height growth may stop altogether or *stagnate*. However, Goudie (1990) believes that even at initial densities of over 100,000 stems/ha height growth does not truly stop. Differences in microsite, genetic potential of trees, and date of establishment will provide some trees with a competitive advantage and these will very slowly outgrow their neighbors (see also section 2.2.4).

2.2.3 Density and Diameter Growth

Diameter growth is negatively correlated with density. At a given site height, average stand diameter will decrease with increased density (Figure 3). Several authors even suggest that, for a given mean tree size, there is a maximum number of stems a site can support (Drew and Flewelling 1979, McCarter and Long 1986, Reineke 1933, cited in Oliver and Larson 1990). When trees in a stand reach this threshold size, self-thinning will occur and density will be reduced. This is known as the -3/2 law because when tree size is plotted against trees/ha on logarithmic axes, the slope of the line will be -3/2 (see Figure 6., sec. 2.3.2).

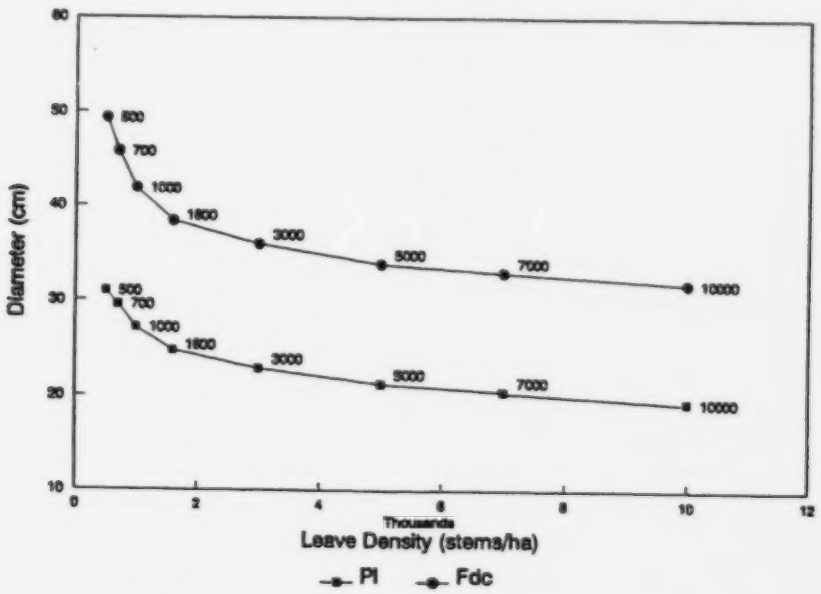

FIGURE 3. Diameter of interior lodgepole pine and coastal Douglas-fir in relation to density at age 90 on "medium" site. (Source: TIPSY Ver. 2.0b 1992. Run parameters for lodgepole pine: naturally established without treatment, site index 18. Run parameters for Douglas-fir: naturally established without treatment, site index 30). Note that, beyond ~1600 stems/ha, diameter is relatively insensitive to changes in density.

2.2.4 Density and Height Growth

Because of priorities in the allocation of photosynthate, a density induced reduction in crown size will result in decreased diameter growth. The correlation between density and height growth is less clear. Even with a diminishing crown, photosynthates may still be available for height growth. In the past it was widely believed that height growth of dominant trees was independent of density. Recent research has shown, however, that height growth is affected at some threshold density (Yang 1991, Johnstone 1985, Cole and Edminster 1984, Goudie 1980). The density at which height growth is affected and the magnitude of effect reported in the literature are variable and appear to be related to stand differentiation, site quality, and species. The greatest effects are seen in less shade tolerant species such as lodgepole pine and Douglas-fir and magnitude is apparently greater on poor sites and in uniform stands. Increased magnitude on poor sites may be a function of less site resources and higher densities. Oliver (1990) suggests that density on poor sites is often greater because smaller crowns with thinner foliage permit more light to penetrate allowing many poorly growing stems to survive (differentiation is slower).

2.2.5 How Age Affects Response To Changes In Density

Stand diameter growth rates at low establishment densities (expressed as 10 year periodic annual increment (PAI) in the figure below) are considerably higher than at high establishment densities within the time frame that spacing or commercial thinning would normally occur. In this example, growth rates begin to converge after age 60.

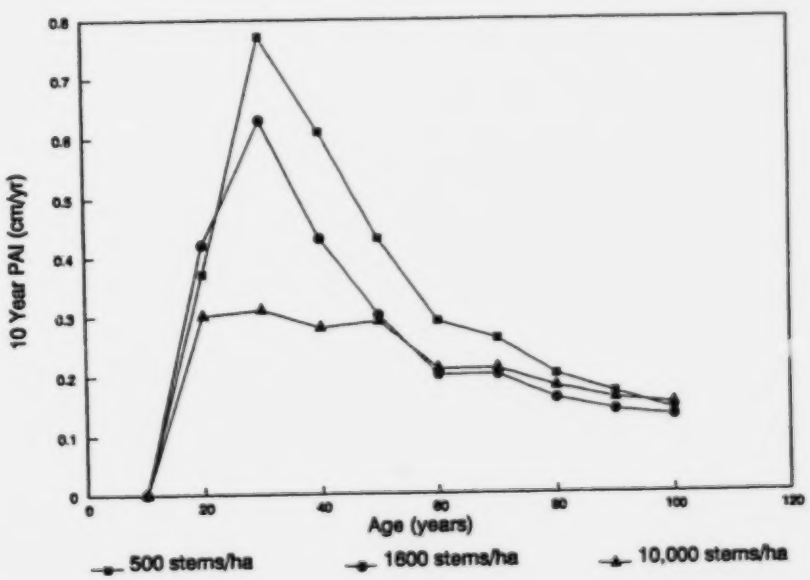

FIGURE 4. Growth rate expressed as periodic annual diameter increment for a lodgepole pine stand on site index 18 in relation to 3 establishment densities (natural) untreated. (Source: TIPSY Ver. 2.0b 1992).

It might be expected, therefore, that diameter growth following spacing in a high density stand would follow a new diameter trajectory similar to that of a low density stand. In older stands this is often not the case, however, because growth rate depends not just on density and age, but also on a trees position in the canopy and crown volume at the time of spacing.

Percent live crown is usually lower in older, taller stands (see Figure 5) resulting in a higher proportion of respirational area to leaf area. An increase in diameter growth is, therefore, often delayed following spacing until sufficient crown volume develops. In dense stands, crown volume relative to respirational demands can be so low that it may be decades before sufficient foliage is produced to permit any significant diameter response (Oliver 1990).

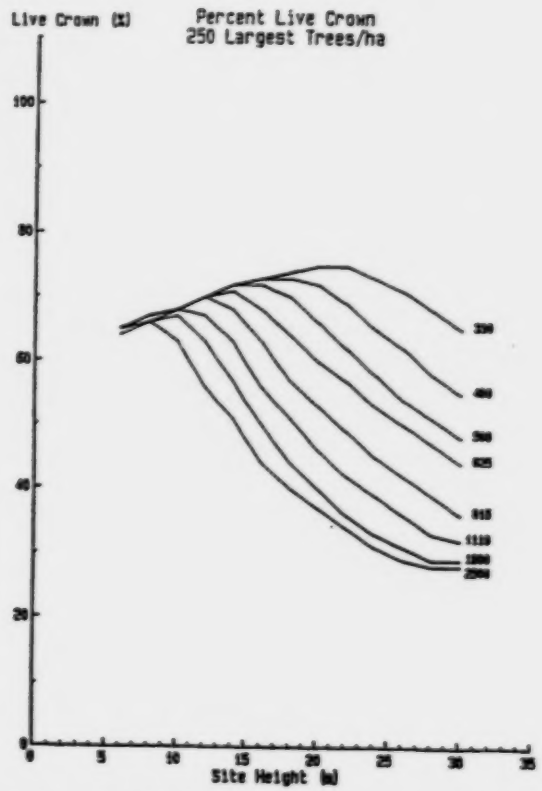

FIGURE 5. Live crown percent in relation to height and initial density. (Source: Goudie *et al.* 1990).

Affleck (1987) correlated response delay in lodgepole pine, coastal Douglas-fir, and coastal western hemlock with height/diameter ratios based on limited studies in the southern interior and south coast of B.C.. The height/diameter ratio is a reflection of crown development since height growth is relatively independent of crown volume but diameter growth is immediately affected by it. A low height/diameter ratio for example, implies that crown volume during stand development was relatively large and good diameter growth was maintained.

TABLE 2. Response delays associated with various height/diameter ratios (height in meters/diameter in centimeters X 100). (Source: Affleck 1987).

Canopy Strata	H/D Ratio Fd	Pl	Hw	Response from Release
Open	50 - 60	60 - 70	60 - 70	N/A
Dominant	60 - 70	70 - 80	70 - 80	Immediate
Co-dominant	70 - 80	80 - 90	80 - 90	2 + years
High Intermed.	80 - 90	90 - 110	90 - 100	5 + years
Low Intermed.	90 - 100	110 - 130	100 - 110	10 + years
Suppressed	100 +	130 +	110 +	15 + years to never

Note: These values represent generalized relationships and should not be used for operational purposes unless substantiated with local data..

This relationship appears to be more pronounced in shade intolerant species since shade tolerant species generally maintain a higher percent live crown (Handley, pers. comm. 1992). From a biological point of view, then, the decision to space a stand is primarily a function of size and health of the crown. In general, crown volume in dense stands is likely to diminish relative to respirational needs as the stand gets older and this will result in reduced response.

2.3 The Impact Of Stand Density On Yield

2.3.1 Yield Relationships

Yield is different from growth in that it represents the volume of wood produced up to a specific age. Growth is the rate of wood production . A fundamental principle of yield theory is that, beyond a certain threshold, *final* yield is relatively independent of density (Langsaetter 1941 cited by Smith 1962, Oliver 1990, Kira and Shinokazi 1956 cited by Nawitka 1987). In other words, the land has a fixed capacity to produce a certain volume and this volume will be allocated to either many small stems or a few large stems. This is known as the theory of constant final yield.

While yield for a range of densities may tend to converge at some future point, it is clear from Table 3 below that, initially, growth rates, and therefore yield, vary with density.

TABLE 3. Relationship between density and volume, mean maximum annual increment (MAI) and maximum current annual increment (CAI), for interior white spruce on site index 17. All volume figures represent cubic meters/ha with a merchantable dbh of 12.5 cm. (Source: TIPSY Ver. 2.0b 1991).

Initial Density	Merch Vol. at 200 years	Merch Vol. at 100 years	Max. CAI	Age of Max. CAI	Max. MAI	Age of Max MAI
10,000	677	397	8.2	48	4.1	110
5,000	678	403	8.2	65	4.2	110
1,000	688	342	6.8	88	3.8	130
500	592	257	5.6	88	3.0	130

Several conclusions can be drawn from these data:

- MAI and CAI change at a given age depending on density.
- growth rates (CAI and MAI) are initially greater and occur earlier at higher densities.
- CAI culminates earlier and higher than MAI.
- although, with time, merchantable volumes will tend to converge, initially merchantable volume is greater at higher densities.
- wider initial spacings (including spaced stands) do not shorten the time to culmination of MAI, they lengthen it (growth rate peaks later because the site remains less than fully stocked for a longer period).
- juvenile spacing may not result in increased merchantable yield.

Although not shown in Table 3 above, it should also be noted that the difference in rate of growth (MAI) between spaced and unspaced stands is greater on poorer sites and, as merchantable diameter limits are increased, MAI will decrease and at some diameter limit the unspaced stand will have a lower MAI at rotation than the spaced stand.

The relationships described above might lead one to the conclusion that it is not worthwhile to juvenile space. There is a very important reason this conclusion could be wrong. These relationships are based solely on volume and, as can be seen in Table 4 below, diameter at some rotation age can be greatly increased on a wide rage of sites by reducing density.

TABLE 4. Diameter (cm) at age 80 for a range of initial densities (Site Index 20). (Source: TIPSY Ver. 2.0b 1991)

Initial Density	Fdc	Fdi	Hwc	Pl	Sw
10,000	-	16.0	19.7	20.7	19.3
5,000	18.7	17.6	21.1	21.7	20.3
1,000	26.5	25.6	28.4	28.2	26.2
500	31.2	30.4	32.5	32.2	29.7

In financial terms, obtaining larger logs in less time through density control, can result in large economic returns (see sections 3.2 and 3.3). The decision to space, then, is dependent on the trade-offs between diameter, volume, and time.

A final point with respect to diameter is that dense stands on poor sites (lodgepole pine in particular) may not reach a merchantable size in a reasonable time. Table 5 below, for example, shows that, without juvenile spacing, pine on poor site may take 275 years to reach an average stand diameter of 15 cm. When that same stand is spaced, merchantability will be achieved in only 54 years, a difference of 221 years. Making that wood available within the time frame normally used in AAC calculations, may have an important bearing on the decision to space, despite the fact that spacing is very unlikely to be economical in such circumstances (for further discussion of this concept, see section 3.5.4).

TABLE 5. Time (years) for lodgepole pine to reach an average stand diameter of 15 cm dbh. (Source: TIPSY Ver. 2.0b 1991).

Regime	Site Index 10	12	14
Initial density 10,000, no treatment	275	178	127
10,000 spaced to 800 @ 4 m	57	47	40
10,000 spaced to 500 @ 4 m	54	45	39

2.3.2 Achieving Optimum Stocking

Stocking is the proportion of an area actually occupied by trees (how much of the site is being used by trees). In the past, a basic tenet of forestry has been to keep the site as fully stocked as possible. Presumably this meant to control density and distribution such that established trees are fully utilizing site resources. Simply stating stems/ha or basal area/ha does not indicate the proportion of the area occupied by trees.

In order to determine if a site is fully occupied, density must be expressed relative to carrying capacity. For example, the maximum volume of wood a particular pine site could grow at age 100 might be 400 m^3/ha. If a stand at this age has 300 m^3/ha then it would be 75% stocked (300/400x100). Several helpful guides have been developed to help determine stocking. Two of the most common are shown below.

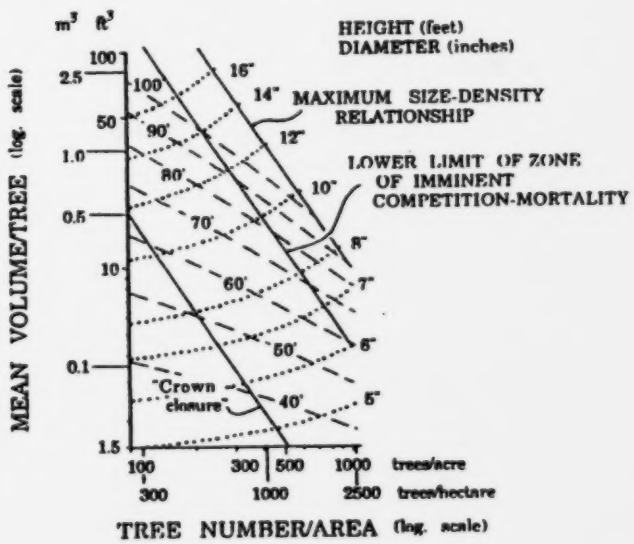

FIGURE 6. Density management diagram for coastal Douglas-fir. (Drew and Flewelling, 1979, adapted from Oliver, 1990).

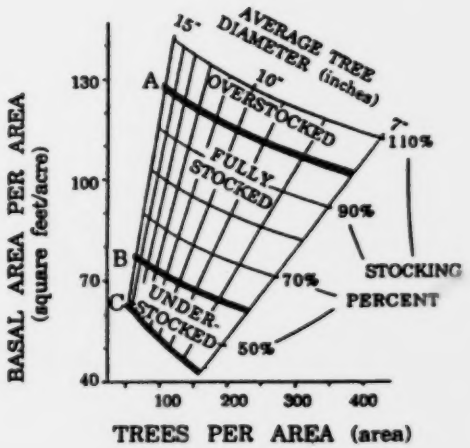

FIGURE 7. Basal area diagram relating basal area, diameter and tree number to stocking. (Gingrich, 1967, adapted from Oliver, 1990).

Yield tables generated by TASS are used in another program called TIPSY (Table Interpolation Program for Stand Yield). This program allows the user to specify the species, number of trees established, regeneration method, site index, spacing regime, regeneration delay, and two kinds of operational adjustment factors. It interpolates from TASS yield tables to produce a new yield table for a specified range of ages or site heights. TIPSY can be used on a personal computer and in our yield analysis we used it whenever possible (Version 2.0b produced in Dec. 1991). TIPSY does not allow one to change the age at which spacing occurs, however, nor does it provide a complete range of initial densities or treatment regimes. Where these limitations prevented us from obtaining the yield information required, Research Branch conducted new runs for us using TASS.

Although we believe TASS provides the best yield information available, it has several limitations. These are:

- height repression is not modelled.
- it models all stands from germination and cannot, therefore, model existing older stands using the age and density they are currently at (see section 3.3 for further discussion of this concept).
- stand dynamics and yield in mixed stands is modelled relatively poorly (although it is as good as other models).
- juvenile spacing data are limited reducing the reliability of growth response information.

The first limitation necessitated an adjustment to TASS/TIPSY yields to more accurately reflect operational circumstances. This is explained in subsequent sections. The second limitation was not relevant in this study. With respect to the last 2 limitations, we had no defensible basis for adjusting yields. It should be noted, however, that we do not expect either of these later two limitations to make a significant difference in most cases since:

- although there are relatively few *spaced* stands in the data base, there are a large number of stands in a wide range of *establishment* densities.
- with respect to mixed stands, it is expected that spacing will normally be conducted in stands dominated by a single species or mixed species with similar growth habits.

3.1.1 Adjustment Factors

As noted above, adjustments to TASS/TIPSY yields were required for height repression. Because stands used in the TASS data base are fully stocked, carefully maintained research installations, an adjustment was also necessary to account for stocking voids encountered in operational conditions. Adjustments were made as follows:

Voids

To better reflect operational conditions a 15% reduction in yield was applied to all simulation runs. This reduction basically deletes 15% of the land base from crop production and, therefore, while it reduces the total volume produced, it does not affect the diameter or height growth of remaining trees.

Height Repression

The repression of height growth of dominant trees in dense stands (see section 2.2.3) is not modelled by TASS, despite a considerable body of literature supporting this notion. At the time, the Forest Productivity and Decision Support section of Research Branch felt there was insufficient data to support any conclusions about magnitude of effect (K. Mitchell, pers. comm. 1991). In preparation of this report we concluded that the paucity of data in most cases continues to preclude accurate incorporation of height repression information in yield analysis. With respect to lodgepole pine, however, there have been sufficient analyses/studies (Yang 1991, Thrower 1991, Moss 1990, Johnstone 1985, Goudie 1980) that we felt it was justified to include a tentative height repression factor in the juvenile spacing guidelines. Yields and associated financial returns for regimes where repression has been incorporated should be used with caution, however, until further research substantiates these interim findings.

In our analysis the repression factors we used were 1.0 m, 2.0 m, and 3.0 m for pre-spacing densities of 7000, 10,000, and 20,000 stems/ha respectively. These numbers represent the reduction in site height from potential site height at breast height age 50. In other words, a reduction in site index of 1, 2, or 3 meters.

The values chosen were based on reported findings from limited research in B.C. and Alberta by Thrower (1991), Johnstone (1985), Yang (1991), and Moss (1990). It is probable that the magnitude of effect varies not only with density but also site quality, however, there was no consistent trend in the data and therefore, the magnitude used was based solely on density. The numbers used are lower than the average values of the four researchers. Lower values were used because when repression is expressed as a reduction in site index, both height and diameter are reduced and diameter growth reductions at higher densities have already been accounted for in TASS. The results of a sensitivity analysis show that the repression factors do make some difference in yield (Table 8).

TABLE 8. Merchantable yield of untreated lodgepole pine with and without repression factors at age 100 (merch dbh = 12.5 cm vol is expressed in m^3/ha and diam. is expressed in cm). (Source: TASS Ver. 2.04 and TIPSY Ver. 2.0b 1991).

	Potential Site Index					
	14		18		22	
Density	Vol	Diam.	Vol	Diam.	Vol	Diam.
w/repression						
20,000	140	10.5	273	15.9	433	22.6
10,000	162	12.8	298	17.6	421	24.2
7,000	198	14.9	340	19.8	475	26.2
no repression						
20,000	220	14.8	363	21.6	464	24.4
10,000	227	15.2	366	21.1	486	27.4
7,000	231	16.0	375	21.8	509	27.9

Note that these repression factors apply only to the unspaced control stand and were not used on species other than pine. Where spacing occurs at a site height of 4 m or less, no repression occurs. This is not the case in older stands where spacing has been deferred.

As noted in section 2.2.1, crown volume in dense stands is likely to diminish relative to respirational needs as the stand gets older. At the request of regional MoF representatives, we produced yield and financial tables corresponding to these older stands for pine, coastal Douglas-fir, and coastal western hemlock. Spacing was simulated at site heights of 10 and 17 m for pine and 12 m for Douglas-fir and hemlock. To reflect the reduced capacity of repressed ***pine*** stands to respond, we applied the repression factors noted above (1, 2, and 3 meters) to both the control (unspaced stand) and spaced stand where initial stand density exceeded 7000 stems/ha and site height was 10 m or greater. Note that these repression factors were used ***only*** with pine. The effect was a considerable reduction in yield relative to no repression factor for the treated stand (Table 9).

TABLE 9. Merchantable yield of lodgepole pine at age 100 with and without repression factors in stands spaced at 10 m site height (merch. dbh 12.5 cm, vol expressed in m^3/ha, diam. expressed in cm). (Source: TASS Ver. 2.04 and TIPSY Ver. 2.0b 1991).

	Potential Site Index					
	14		18		22	
Density	Vol	Diam.	Vol	Diam.	Vol	Diam.
w/repression						
20,000 to 800	104	18.9	222	24.4	380	29.1
10,000 to 800	132	20.7	264	25.5	440	30.4
7,000 to 800	160	22.1	304	26.7	486	31.5
no repression						
20,000 to 800	186	23.0	337	27.8	524	32.4
10,000 to 800	189	23.0	351	27.8	525	32.8
7,000 to 800	191	23.3	344	27.6	529	32.6

3.1.2 Benchmark Site Indices

These spacing guidelines address yield and financial returns for six species, up to five initial densities, up to nine treatment densities, up to three spacing heights, three logging/hauling difficulty classes, and three benchmark site indices, resulting in a maximum total number of possible combinations of over 7000. In order to keep the number of tables to a minimum (Appendix 1), we limited the number of site types we would address to three benchmark examples for each species as follows: Fdc - 25, 30, 35; Hwc - 23, 28, 33; Fdi - 16, 21, 25; Hwi - 12, 16, 20; Pl - 14, 18, 22; and Sx - 13, 17, 21. Although this may seem somewhat restrictive, limited testing we have performed indicates that interpolation of intermediate values in the financial tables will yield a reasonably accurate approximation.

Benchmark indices were chosen based on two sources of information; the MoF inventory data base and the personal experience of 12 different groups of foresters around the province. A special report stating area by site class for age class three and less stands in six typical TSA's around the province was prepared by Inventory Branch. This report was used to get a preliminary indication of the relative importance of each site class. Benchmark indices were not chosen based on this information alone because:

- each class encompasses a range of site indices,
- inventory data is sometimes unreliable with respect to site index, and
- the probability of spacing is not necessarily correlated with the amount of area in a particular site class.

This information was used in conjunction with suggested benchmark indices of various foresters. These foresters based their opinions on knowledge of site quality in their areas of operation and on where they believed spacing was most likely to occur in the next five years.

All site indices in the report represent the total average height of the 100 trees of largest diameter per hectare (top height) when they reach 50 years of age measured at breast height. The MoF inventory data base and other sources often report site index using a base age of 100 or simply report site class rather than site index. To facilitate conversions from such reports and from MoF Forest cover maps, we prepared the conversion table shown below. The range of site indices (base age 100) associated with each site class were provided by Inventory Branch. Conversions to base age 50 were calculated using a Research Branch program called Freddie.

TABLE 10. Site index by site class.

	GOOD		MEDIUM		POOR		LOW	
Species	Base Age 100	Base Age 50	Base Age 100	Base Age 50	Base Age 100	Base Age 50	Base Age 100	Base Age 50
Fdc	>42.7	>31.3	30.5 - 42.7	22.7 - 31.3	18.3 - 30.4	13.9 - 22.7	<18.3	<13.9
Hwc	>39.6	>26.9	27.4 - 39.6	18.1 - 26.9	15.2 - 27.3	9.9 - 18.1	<15.2	<9.9
Fdi	>27.4	>19.0	21.3 - 27.4	14.9 - 19.0	12.2 - 21.2	8.8 - 14.9	<12.2	<8.8
Hwi	>30.5	>20.3	24.4 - 30.5	16.0 - 20.3	12.2 - 24.3	8.0 - 16.0	<12.2	<8.0
Pl	>24.4	>18.2	18.9 - 24.4	13.4 - 18.2	12.2 - 18.8	8.2 - 13.4	<12.2	<8.2
Sx	>25.9	>17.1	19.8 - 25.9	12.4 - 17.1	12.2 - 19.7	7.5 - 12.4	<12.2	<7.5
Ss	>39.6	>26.9	27.4 - 39.6	18.1 - 26.9	15.2 - 27.3	9.9 - 18.1	<15.2	<9.9

(Base age 100 means total height at 100 years total age, base age 50 means total height at 50 years of age measured at breast height.)

3.2 Methods Used In the Economic Analysis

3.2.1 Basic Methodology

The approach used is a variation of benefit-cost analysis. Vital elements to the procedure are 1) how the benefits are calculated and used, 2) what the costs are and how they are used, and 3) the use of the resultant B/C ratio. There are a number of points affecting the analysis which are unique to forestry investments such as spacing:

- large numbers of relatively small investment opportunities are being evaluated.
- frequently the objective is to accomplish as much as possible within a specified budget.

- for each opportunity, no treatment is an option that must be evaluated.
- budgets (investments) are compared and allocated between competing areas.
- as spacing can change the rotation length and hence the accumulated cost of yearly administration and management, an annual carrying cost is appropriate. If it was not included, long rotations for untreated stands would have a financial advantage.

3.2.2 Calculation of Discounted Net Revenue

The future net revenue is the timber value expected from harvesting one hectare at the end of the rotation, less the cost of logging and hauling the timber to a utilization center. The future net revenue figure is then discounted at 4 percent to the time the spacing would have taken place. The effects of inflation are omitted from the analysis for both the revenue and the costs.

The calculation, in addition to the above basic procedure, included an annual carrying cost at a compound interest rate of 4 percent from the time of spacing to the end of the rotation. Carrying costs are shown in Appendix IV as is a flow chart detailing the above calculation.

Timber value (price) files as well as logging cost and hauling cost files are shown in Appendix IV and are discussed in section 3.2.4. Note that timber values have been related to the average diameter of the stand. This is necessary because large stems are more valuable than smaller stems (high product value and efficiency of manufacturing) and are cheaper and easier to extract and haul.

In conjunction with the timber price files the consultants also used real price increase schedules (see Appendix IV). The schedules were used to introduce a real price increase, up to a maximum of one percent, for growing larger logs. Empirical evidence indicates that this fits the B.C. situation (see section 3.2.5) and that a real price increase has occurred for larger sawlogs which produce premium sized lumber. The one percent rate was chosen in consultation with Ministry economics staff.

Discounted net revenue (DNR) was calculated using a spread sheet model for a variety of stand conditions and was presented in tabular form by regime (region, species, regeneration method, initial density, site index, post-spacing density).

3.2.3 Use of Discounted Net Revenue

DNR is used to evaluate the economic potential for treatment. In order to propose treatment the DNR of the spaced stand must exceed the DNR of the untreated stand by an amount that exceeds the anticipated cost of spacing. If the additional value created by treatment exceeds the cost of treatment, the stand is considered to be treatable and can be assigned a B/C ratio to establish its priority for treatment.

The DNR's shown in Appendix I are the difference between the spaced stand and the unspaced stand - in other words the DNR attributable to spacing. This facilitates the application of the table since the DNR figure can then be compared directly to the anticipated cost of spacing. To determine the value of the spaced stand, add the appropriate DNR for the untreated stand (shown in Appendix II) to the DNR attributable to spacing from Appendix I.

The procedure can be summarized as follows.

Where:

B0	=	discounted net revenue from the control or the stand without treatment
B+	=	discounted net revenue from the best treatment option (i.e. number of crop trees left)
C	=	current estimated cost of spacing

The stand is treatable if: B+ minus B0 is > C

Assigning priority:

A priority for spacing the stand is calculated as the ratio of benefit to cost:

(B+ - B0)/C = numerical priority

A higher numerical value represents a higher priority.

3.2.4 Calculation of Timber Values and Logging Costs

Timber values were calculated using a net down procedure similar to the appraisal calculation used for Interior mills. The selling price of the end product (lumber and pulp chips) less the cost of manufacturing, including overhead and a return on investment, were considered to be the market price of the timber delivered at a mill. The standing value of the timber was considered to be the delivered mill value less logging and hauling costs.

Lumber selling prices were compiled using data from various issues (1986 to 1990) of Random Lengths, Random Lengths Export, and Madison's Canadian Lumber Reporter. Chip prices were taken from Nawitka (1990). Nawitka file data, Sterling Wood Group (1988) and Goudie *et al.* (1990) were used to establish lumber and chip recovery and to relate product recovery to average stand diameter.

Manufacturing costs were compiled using Nawitka file data, Sterling Wood Group (1988), Howard (1991) and Statistics Canada data taken from Forestry Canada (1990).

Logging costs were compiled on the basis of tree-to-truck costs. Nawitka file data and Sterling Wood Group (1989) were the major sources. Hauling costs were compiled from data taken from the same sources but supplemented with data provided by the Regional Offices of the Ministry of Forests. The haul distances chosen were based on estimates provided by Regional Ministry staff with respect to the location of potential spacing and the distance to utilization centers.

Files for the above items showing the figures used are detailed in Appendix IV.

3.2.5 Log Prices in the Future

Clearly, one of the critical variables in treating softwood stands in B.C. is the expectation or forecast regarding the prices of logs of different types in the future.

The historic record is quite clear: sawlogs and lumber have enjoyed scarcity price increases of 1 - 2% per annum for nearly 200 years in North America. That is, their prices have increased faster than other goods and services (prices in general).

Pulpwood and other low grade industrial woods have had relatively constant prices - that is, have kept up with inflation, and have remained about the same with relation to other industrial materials and services.

Potter and Christie (1962) noted the startling conclusion that sawlogs and lumber were the only resource commodities which showed this price behavior, of all North American natural resources. Soon after, Barnett and Morse (1963) noted the risks of substitution and questioned whether the historic trend could last.

Manthy (1978) updated these earlier studies by Resources for the Future, noting that although the trend had continued, it was showing signs of flattening out, and likely would level by the 1990's. Figure 10 shows data on U.S. lumber prices from 1805 to 1990 (USFS). The trend continues, but analysts can again point to a leveling off, even a relative decline over much of the past two decades.

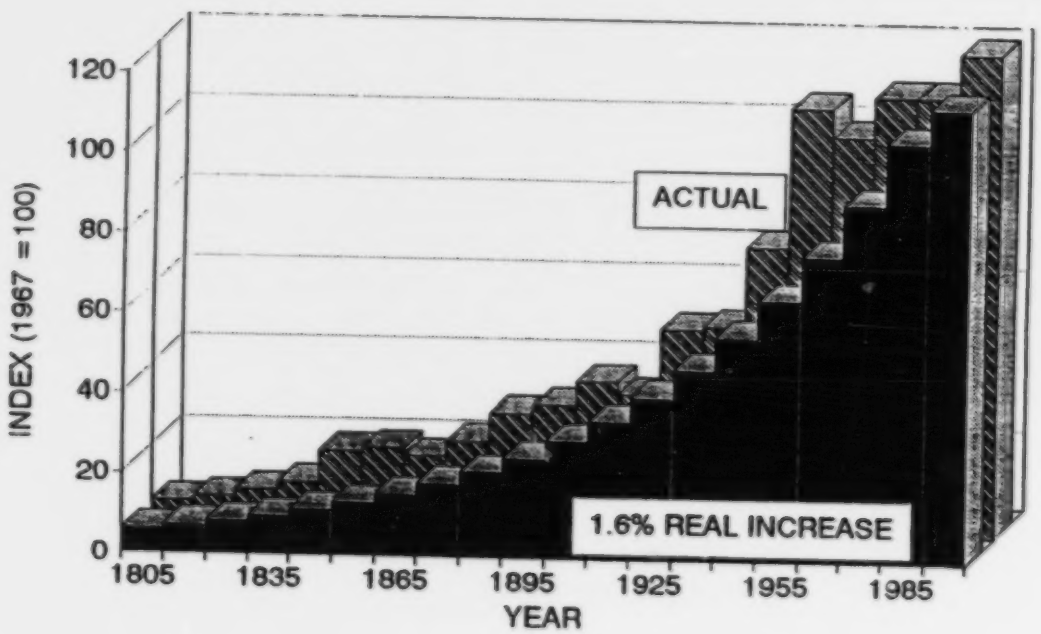

FIGURE 10. Relative producer price index for U.S. lumber (1805 - 1990).

In assessing the future of "industrial wood" prices in North America, Sedjo (1990b) notes that:

> "The price behavior of the four decade period since 1950 suggests the possibility of a fundamental change in the long term balance in the supply and demand for industrial wood in the U.S."

Supplies from Canada are included in this analysis and in the earlier treatment of global supply and demand for timber by the same author (Sedjo 1990a). The basic conclusion is that timber as a raw material is no longer showing scarcity price behavior in world markets. However, there are two major weaknesses in the study and its logical conclusion, from a B.C. policy point of view. These are:

- the mixing of sawlogs, pulpwood and other industrial wood in one commodity
- inadequate treatment of the impact of exchange rates on real prices, particularly in North America

Industrial Wood

The argument for one industrial wood class involves technological change, as well as a general decline in timber size and specialty grade in most regions. For example, particleboard panels displace plywood from some uses even though the inputs to the former are small, low-grade logs compared to normal ply-logs. There are new ways to replace more expensive types of wood with less expensive. However, real enhancements of size, appearance and performance characteristics still command higher log prices in all markets. Mixing the data eliminates the scarcity in the model, but not necessarily in reality. The owner of the higher quality material may well continue to enjoy relative price increases in future. In fact, most of the disaggregated price series for select species and grades continue to show 1-2% real increments over the past 40 years (Sedjo 1990a).

In general, BC softwoods are in the "high-end" of the wood quality and performance spectrum - we should not confuse our long term price projections with those of pulpwood, or even with the average of "industrial wood".

Exchange Rates

In the Resources for the Future review of world timber outlook (Sedjo 1990a), exchange rates are necessarily given summary treatment, since they could immensely complicate the analysis. The U.S. dollar provides the best historic and projected base currency and is used for this purpose. To the extent that other currencies, or international mixtures set the standard in future, the results may be somewhat different.

More significant for B.C. policy purposes, the study assumes that the Canadian dollar will closely track the U.S. dollar within North America - or at least will follow the same relative pattern. There can be no quarrel with this historic reality in the long run. Within a lasting Free Trade Agreement, convergence is likely within a decade or two. However, there have been significant divergences from this pattern in the past thirty years (Figure 11). Yet any past impacts of the Canada-U.S. exchange rate are ignored. Some real impacts seem likely to have occurred in the past thirty years, and any changes in these exchange rate patterns and shifts in the future may have significant impact on North American commodity price trends.

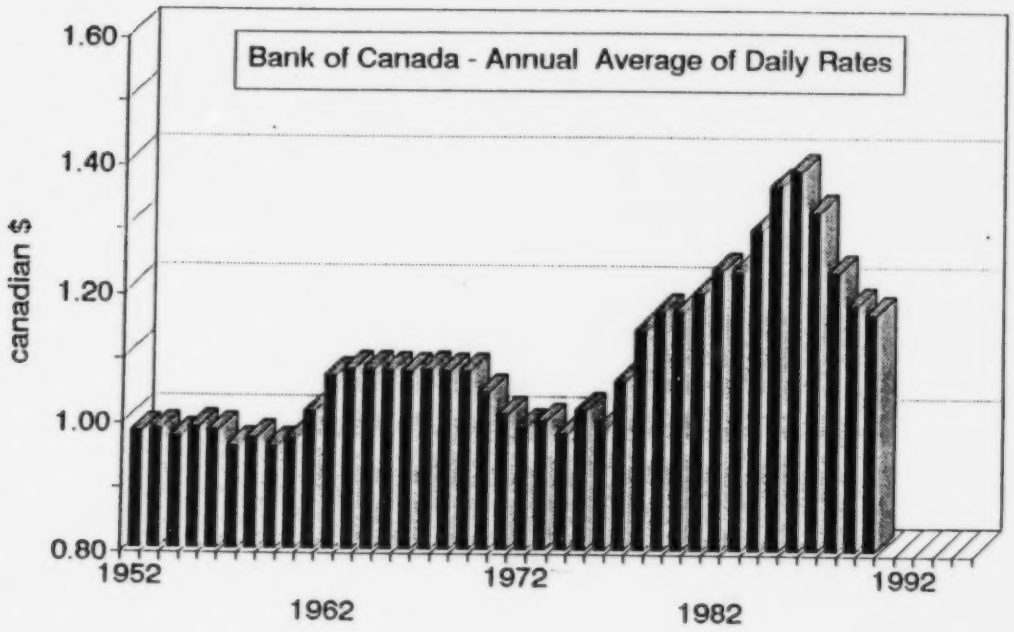

FIGURE 11. The price of the U.S. dollar in Canada (1952 - 1990). (Source: Bank of Canada).

One likely impact of a sharply devalued Canadian dollar, within North America, would be increased exports of lumber from Canada to the U.S. in the short run. The immediate impact of the devaluation is a higher return to the Canadian mill.

Within this highly competitive market, where sales are often made over the phone with the product ready for shipment (sometimes already rolling down the rails or at destination in the 1960's) it is easy to imagine some of the potential exchange "profit" being bargained away by the producer in the form of a reduced offer price. One would even perhaps predict an increase in the Canadian share of the U.S. lumber market.

After the sharp devaluation (roughly 10%) of the early 1960's, the Canadian share of the U.S. lumber market rose by about 60% (from 12 - 14% to about 20%). During the sharp and steady devaluation (roughly 30%) from 1976 to 1986, the Canadian share of the U.S. lumber market again rose by about 60% from approximately 20% to 33%.

Could these devaluations, adjustments, and movements in market share have undermined the real price of lumber in North America? This study cannot answer that question. In the current environment of countervail debates, it can only be raised with some trepidation. Figure 12 provides only a crude picture of the potential shadow, or footprint of Canadian devaluation in U.S. lumber markets. The fact that hardwood lumber markets (where Canada plays a very minor role) show a more steady upward trend with less severe adjustments may be significant, but many different market variables are at work in each.

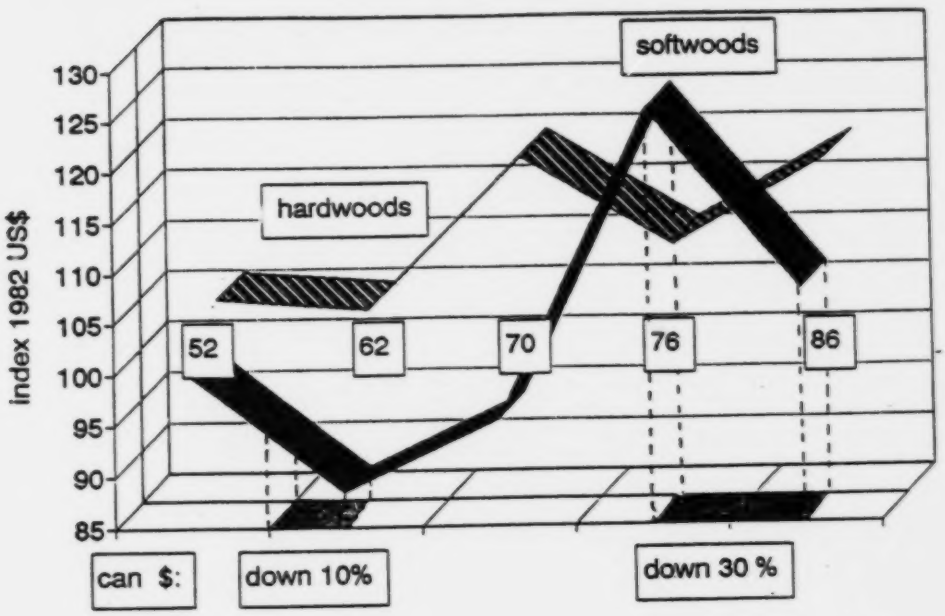

FIGURE 12. Periodic lumber price index in relation to devaluation of the Canadian dollar (1952 - 1986).

One clear indicator of some impact on lumber price trends has been the reaction of the U.S. Forest Industry. The first major U.S. study of B.C. and other Canadian stumpage policies occurred after the sharp devaluation of 1962. The succession of more recent countervails were initiated during the 1976 - 86 devaluations.

Another relevant indicator of real price trends for sawlogs can be found in log export prices. Figure 13 shows the average real price of U.S. softwood sawlog exports to all destinations from 1930 to 1988 (Flora *et al.* 1991). The real price trend shows a 1% annual increase, though with increasing volatility in recent decades.

The risks of counter-cyclical production/shipments, and perhaps some impact of a devalued Canadian dollar, are illustrated in the recessive period of the early 1980's, when B.C. log exports rose sharply to maintain employment.

A more detailed analysis of the impact of exchange rates on all forest products trade was conducted by Forestry Canada (Roberts 1988). The study points out that exchange rate effects should be transitory, with adjustments to domestic wages and other input prices gradually compensating for the initial effects. However, this study was most concerned with the impacts of an appreciation of the Canadian currency, after 1986. The study makes no attempt to gauge any impacts on product prices of past devaluations. Relative costs, and market shares have continued to adjust as the Canadian currency has stabilized around US$0.85 in the past few years. The relative price of lumber is currently back on its two-century path.

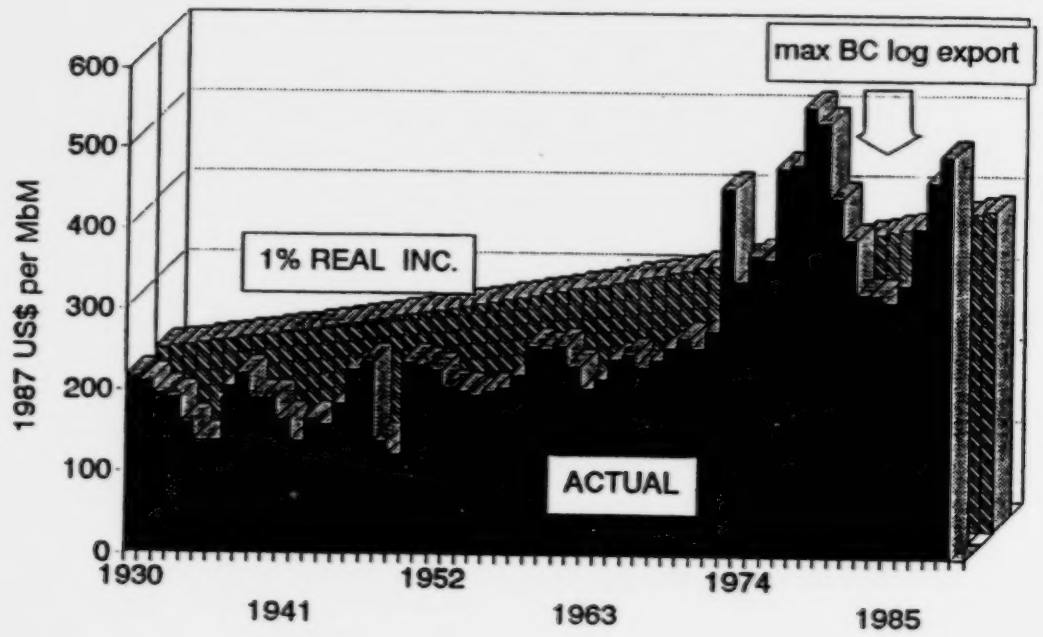

FIGURE 13. The average real price of U.S. softwood sawlog exports (1930 - 1988).

The conclusion for forest policy in B.C. is that it is likely premature to conclude that the historic scarcity prices of lumber (and derived prices for sawlogs) have leveled off in North America. The paper value of the Canadian currency with respect to the U.S. dollar may have undermined the real price of these products over the past thirty years. Thus the evidence being used to conclude that scarcity is over may be flawed. The real value will be reasserted over the next two decades, in any event. Further sharp devaluations of the Canadian dollar seem highly unlikely within the Free Trade Agreement.

A recent analysis and projection by Haynes and Adams (1992) concludes that the most likely scenario is for softwood lumber prices to grow at about 1.4% in real terms to 2010, and more slowly thereafter, with an average increase of 0.7% over the next 50 years. This projection includes continual slow growth of lumber and wood products consumption in North America, in the face of any apparent substitution effects. It has been assumed in this analysis, therefore, that the price of larger softwood sawlogs will rise by 1% per annum in real terms.

We also believe that pulpwood, and other lower grade industrial wood, will maintain its relative value without any real price increase in the long run.

3.2.6 Sensitivity Tests

Sensitivity tests were conducted to show the effect of real price increases for large diameter logs. These tests were conducted for coastal Douglas-fir and interior white spruce for medium site. The tests show the effect of a variety of initial densities and leave densities, the effect of using yield table merchantable volume instead of operational volume, and the effect of omitting the annual carrying cost from the DNR calculation with respect to no real price increase, a real price increase of one percent on all logs, and a real price increase of one percent on large logs only.

It is apparent in Table 11 for Douglas-fir that, with a one percent real price increase, the discounted net revenues from treatment increase, particularly as fewer stems are left. Also, the increase is slightly higher for a higher leave density when a one percent increase is used on all logs. When the increase is used only for large logs, higher leave densities produce less value but low leave densities produce large discounted revenues. Spacing to a low density significantly increases value with or without a real price increase. If a real price increase is used on large logs only, the increased value is again substantially higher than for an increase on all logs. If total volume rather than operational volume is used, the discounted net revenues increase regardless of any real price increase. The additional value produced is proportional to the increase in volume.

The deletion of the annual carrying cost has little effect on discounted net revenues. This is because the cost applies to both the untreated stand and the treated stand. Note, however, that the inclusion of the charge can decrease rotations in general (low carrying costs and low discount rates favour long investment periods). In this analysis the large rotation interval of 10 years masks most, if not all, of this effect.

TABLE 11. Sensitivity Tests, Coastal Douglas-fir, Site Index 30, $DNR/ha.

Regime[1]	No Real Price Increase	Real Price Increase 1% All Logs	Real Price Increase 1% Large Logs Only
4,444/1,110	528	661	644
at 100% vol.	622	783	756
no ann. cost	529	649	639
4,444/900	769	1061	1005
4,444/700	874	1185	1529
4,444/500	1173	1570	2879
at 100% vol	1378	1847	3385
no ann. cost	1174	1558	2874
2,500 planted 1,000	578	947	973
2,500 planted 500	1257	1911	3018
at 100% vol	1479	2242	3545
no ann cost	1258	1904	3007

1. 4,444/1,110 = Initial Stand Density/Density after spacing

   at 100% vol. = The volume used was the yield table merchantable volume without the 15% operational reduction

   no ann cost = The annual carrying cost for stand administration and management was eliminated from the DNR calculation.

   Stands were of natural origin unless specified as planted.

In Table 12 for white spruce a similar situation can be seen. While spruce is less valuable than Douglas-fir, the net discounted revenue from treatment increases as fewer stems are left. Again the increase is slightly higher for a higher leave density when a one percent increase is used on all logs. When the increase is used for large logs only, higher leave densities produce less value and lower leave densities produce more value. If total volume rather than operational volume is used, the discounted net revenues increase regardless of any real price increase and the additional value produced is proportional to the increase in volume. The deletion of the annual carrying charge again has little effect.

TABLE 12. Sensitivity Tests, Interior White Spruce, Site Index 17, $DNR/ha.

Regime[1]	No Real Price Increase	Real Price Increase 1% All Logs	Real Price Increase 1% Large Logs Only
10,000/1,400	229	438	312
at 100% volume	269	515	367
no ann. cost	225	436	311
10,000/1,000	304	551	497
10,000/600	365	558	846
at 100% vol.	428	656	996
no ann. cost	361	556	845
5,000/1,400	166	282	213
5,000/1,000	222	352	374
5,000/600	267	338	682
1,600 planted 800	143	189	370
1,600 planted 600	163	170	518
at 100% vol.	191	201	610
no ann. cost	162	170	518

1. 10,000/1,400 = Initial Stand Density/Density after spacing

at 100% vol. = The volume used was the yield table merchantable volume without the 15% operational reduction

no ann cost = The annual carrying cost for stand administration and management was eliminated from the DNR calculation.

Stands were of natural origin unless specified as planted.

Operational volumes, an annual carrying cost, and real price increase of one percent for large logs only were used to produce the DNR tables in this report.

The use of a real price increase for larger logs on the Coast produces significantly higher values. Note, however, that low leave densities remain the best option regardless of any real price increase. In the Interior, the same is true but the value created by spacing in most cases is insufficient to cover spacing costs unless a real price increase is considered.

The objective of spacing programs in the Interior should be to produce larger logs in support of sawmilling that produces more valuable lumber items (i.e. larger widths). Fibre and small dimension lumber products do not, in general, justify spacing expenditures. In specific situations, such as reducing rotations to increase wood supply, spacing may be justified but most likely will not meet the four percent investment return guideline.

3.3 Using the DNR Tables to Determine Treatment Priority

3.3.1 Candidate Stands and Regimes

The forest manager determines objectives, non-timber constraints, and other factors, such as site conditions, to identify stands that have a potential for treatment, and then uses the DNR tables to assess financial feasibility and treatment priority. Stand situations and characteristics which must be determined include:

- Region (Coast, Northern Interior, Southern Interior)
- Species
- Site Index
- Initial stand density
- Stand origin (natural or planted)
- Height at which spacing will occur

The list of characteristics shown does not cover all possible situations but sufficient combinations are present to cover most treatment opportunities. Interpolation between the sites and densities shown will give reasonable approximations even though the relationships are not straight line. Interpolation outside the sites and densities shown is not recommended.

3.3.2 Spacing Feasibility and Priority

The DNR in the table for a selected set of characteristics and particular post-spacing (regime) density is the potential discounted net revenue for one hectare of the stand, not including the cost of treatment, that is attributable to spacing the stand. The figure was obtained by subtracting the discounted net revenue attributable to the stand if it were not treated from the discounted net revenue expected from the stand if it were treated. Since the figure is net of all costs except treatment, and has been discounted, it represents current value and can be compared to current treatment costs. If treatment can be conducted for the amount shown, the investment will return the specified rate of 4 percent real. If it can be conducted for less than the amount shown, the return will be more than 4 percent real. If it costs more to treat than the amount shown, then the return would be less than 4 percent real.

If the Ministry specifies an investment rate of return (i.e. a discount rate of 4 percent) as the financial criteria for treatment feasibility, then the tables have immediate application in quickly determining feasibility - the spacing cost should not exceed the DNR number shown [2]. In addition to indicating the financial feasibility of treating a specific stand, the index number derived by dividing the DNR figure shown for a post-spacing density by the estimated spacing cost can be used to determine the relative priorities amongst stand.

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2. Senior management may also consider mitigating circumstances such as timber supply and social welfare (see section 3.5.4).

3.3.3 Example Application and Limitations

The following is an example of how to use Appendix I to determine spacing feasibility, appropriate density, and treatment priorities:

Stand characteristics:

- Northern region
- Lodgepole pine
- Good site (estimated close to Site Index 22)
- Initial stand density estimated at 4,500 stems per ha
- Natural stand
- Stand height estimated at 3.5 meters

Treatment:

Inspection of the DNR's for this situation (Appendix I, page 23) indicates that spacing would provide a significant increase in value at the lower leave densities. At an estimated spacing cost of $600 per ha, four leave densities are feasible. If large knots or juvenile wood are considered to be significant, a density of 800 stems per ha might be chosen. If not, 500 stems per ha provides the best value. Note that 600 stems per ha could also be chosen at a sacrifice of only $69 per ha in value if 100 additional stems were desirable. Choose the highest value possible consistent with acceptable forestry risk.

Treatment Priority:

To determine the relative priority of this stand, the DNR number ($1,156 in this example for 600 stems) is divided by the estimated cost of spacing ($600) and assigned a priority index of 1.93. The program is then priorized on the basis of the index number for each stand. The higher the index number the higher the priority. Table 13 below is a short hypothetical District priority list to illustrate this point.

TABLE 13. Hypothetical District priority list.

Stand ID No.	Number of ha.	Priority Index No.	Est. Cost per ha	Total Cost	Cumulative Cost ($000)	Cumulative Hectares
24-920	10.6	2.43	520	5,507	6	11
1	12.1	2.21	740	8,961	14	23
2	38.4	2.16	740	28,409	43	61
3	37.4	2.13	540	20,207	63	99
4	9.4	1.93	625	5,850	69	108
5	17.8	1.70	600	10,710	80	126
6	25.3	1.68	700	17,710	97	151
7	50.2	1.62	790	39,666	137	201
8	6.8	1.24	810	5,508	143	208
9	23.1	1.03	800	18,448	161	231

In this example, all the stands are treatable as the index numbers all exceed 1.00. The last stand, however, would have a low priority as the discounted net revenue attributable to spacing barely exceeds the estimated cost of treatment. If the District budget was $100,000, in this example, all the stands above the dotted line could be treated.

Priority listings should be updated whenever new spacing cost information becomes available. If spacing bids in general are lower than anticipated, a slightly expanded program may be appropriate; if higher, some lower priority opportunities might have to be foregone.

Limitations:

The DNR tables are based on a real discount rate of 4 percent for all regions. It is easy to see that Coast spacing opportunities appear much more attractive than opportunities in the Interior. The large diameters attained on the Coast command premium prices which in turn are reflected in large values attributable to spacing. In general, the return to spacing on the Coast is well over 4 percent, even on the poorer sites. This does not mean that public funding of forestry investments should be limited to the Coast. Other factors, such as those discussed in section 3.5, must also be considered when allocating spacing funds. Neither does it mean that any amount up to the DNR figure shown should be spent on spacing without careful consideration of spacing costs. The objective is to increase net future revenues, not increase spacing costs.

Juvenile wood and knot size were not incorporated in the DNR calculations. It is possible that these two factors may reduce expected product value (see section 2.4), however, data are insufficient to quantify the effect and they could not, therefore, be used in this analysis (see also Recommended Treatment Densities, section 3.4).

3.3.4 Supplemental Information

In order to assist those using the DNR tables, supplementary forest management information is provided along with the DNR figures (MAI, rotation and average stand diameter). This allows the user to compare financial returns to some of the traditional measures of forest yield. In essence, the value created by spacing is presented relative to the volume, rotation, and stem size that creates the value.

Appendix II shows the statistics for untreated stands. The value shown in this case is the total value attributed to the untreated stand. The value of the untreated stand plus the value attributed to treatment (from Appendix I) would be equal to the total value of the treated stand.

3.3.5 Survey Density and Establishment Density

TASS yield tables are based on establishment densities and the DNR tables are referenced to those establishment densities. Surveys conducted early in the life of the stand (6 m Coast, 4 m Interior), where mortality has not been significant, relate well to establishment densities, but this is not the case with older stands. Based on TIPSY (ver. 2.0b, 1992), Table 14 below provides a summary of the relationship between establishment density and survey density for the DNR tables in this report for older stands.

TABLE 14. Survey densities and establishment density for older stands (stems/ha).

Lodgepole Pine			Coastal Douglas-fir		Coastal Hemlock	
Establ. Density	Density at 10M	Density at 17M	Establ. Density	Density at 12M	Establ. Density	Density at 12M
20,000	12,000	3,700	4,444	3,100	10,000	6,900
10,000	5,600	2,500	2,500	1,900	7,000	5,000
7,000	4,200	2,200	1,200	900	5,000	3,700
5,000	3,200	2,000			3,000	2,300

If, for example, survey results indicate that a 10 m lodgepole pine stand had approximately 6,000 stems per hectare, one would use the DNR table for 10,000 stems per hectare.

3.4 Recommended Treatment Densities and Timing

Recommendations on post-treatment density incorporate both the silviculture and financial aspects of the treatment. In determining an appropriate leave density, a number of principles should be kept in mind:

1. Spacing feasibility and treatment density can be determined using financial analysis which identifies the best combination of diameter, rotation length, and merchantable volume. Using financial analysis (and economic rotations) as a basis for the choice of leave density means spacing can increase or decrease the rotation length and increase or decrease the merchantable yield.

2. Juvenile spacing is a treatment that increases average stand diameter. The increase in diameter is affected by both initial density and treatment density.

3. Spacing supports a "large sawlog" economy. Spacing might not be appropriate with a fibre or "small sawlog" economy.

4. Density recommendations provided below are based on assumptions and objectives discussed in preceding sections. Deviation from these recommendations may be appropriate where, for example, there is high anticipated mortality from pests or a change in relative product value. Where the manager has substantive reason to use other standards, what can be considered to be a justifiable spacing cost, will change.

5. Good and medium site have a higher priority for spacing than poor site.

6. Where the amount that could be spent on spacing (i.e. the DNR numbers in Appendix I) is very large relative to the estimated cost of spacing, every effort should be made to ensure spacing costs are competitive. The objective is not to increase or allow higher spacing costs but to maximize the discounted net revenue after spacing costs have been subtracted from the DNR's shown. In this situation, if a variety of areas and regimes are being considered, it is important to treat the highest priority stands first.

In addition to the general principles described above, an analysis of the results in the DNR tables in Appendix I provides the basis for a number of recommendations and conclusions regarding density control. These have been summarized in the following sections by region and species.

3.4.1 Coast Recommendations

Douglas-fir - General Recommendations:

- Stands with as few as 1,200 stems per hectare can be considered for spacing.
- Financially, there is little difference in spacing at 6 m or 12 m. Preference might be given to the higher height if "better quality" leave trees can be selected at that height. In this situation the financial return from increasing volume and stand diameter over a longer time period is about equal to a lesser volume and stand diameter developed over a shorter time period with a lower discounting cost.
- Post-spacing densities of 400 or 500 stems per hectare yield the greatest financial return.
- Spacing is financially feasible for all sites and initial regimes considered. However, some treatment densities are not feasible.
- Spacing on medium site can provide a greater financial return than spacing on good site in some situations depending on initial density and treatment density. Do not assume all good site spacing options are better than all medium site spacing options for coastal Douglas-fir.
- Do not assume that spacing natural stands is better than spacing planted stands. Note in Appendix I that spacing 2,500 planted coastal Douglas-fir can provide higher financial returns than spacing 4,444 naturally established coastal Douglas-fir.

Douglas-fir - Specific Recommendations:

Regime [2] & Site Index	Treatment Density (stems/ha)	Cost Limitations [1] ($/ha)
Site 35		
4444 n at 6 m	500	2,900
4444 n at 12 m	400 or 500	2,600 to 3,200
2500 p at 6 m	500	3,220
2500 p at 12 m	400	3,710
1200 p at 6 m	400 or 500	2,400 to 2,985
1200 p at 12 m	400 or 500	2,655 to 3,310
Site 30		
4444 n at 6 m	400 or 500	2,900 to 3,400
4444 n at 12 m	400 or 500	2,765 to 3,460
2500 p at 6 m	400	3,830
2500 p at 12 m	400	3,775
1200 p at 6 m	400	3,280
1200 p at 12 m	400	3,185
Site 25		
4444 n at 6 m	400	1,800
4444 n at 12 m	400	1,970
2500 p at 6 m	400	2,075
2500 p at 12 m	400	2,070
1200 p at 6 m	400	1,355
1200 p at 12 m	400	1,460

1. The dollar figures reported are approximate for the treatment density shown. Refer to Appendix I for more accurate figures.
2. n = naturally established stand
   p = planted stand

Coastal Hemlock - General Recommendations:

- Densities of 3,000 stems per hectare or more can be considered for spacing.
- Financially there is some difference between spacing at 6 m and 12 m. While not critical, the spacing heights shown in Table 15 are recommended to achieve maximum return. Spacing at 6 m is more costly than spacing at 12 m because the discounting period is longer. If the value being added by the growth response to spacing is better relative to the higher cost of the longer rotation, 6 m will give better value; if not, 12 m will give better value.

TABLE 15. Optimum spacing heights for coastal western hemlock.

Initial Density	Site 33	Site 28	Site 23
10,000	6 or 12	6	6
7,000	12	12	6 or 12
5,000	12	6 or 12	6
3,000	12	12	12

- Post-spacing densities of 400 or 500 stems per hectare yield the greatest financial return.
- Spacing is financially feasible for all sites and initial regimes considered. However, some treatment densities are not feasible.
- In some situations spacing on medium site can provide a greater financial return than spacing on good site.

Coastal Hemlock - Specific Recommendations:

Regime [2] & Site Index	Treatment Density (stems/ha)	Cost Limitations [1] ($/ha)
Site 33		
10,000 n at 6 m	500	4,180
10,000 n at 12 m	500	4,230
7,000 n at 6 m	500	3,875
7,000 n at 12 m	400 or 500	2,790 to 3,425
5,000 n at 6 m	500	3,920
5,000 n at 12 m	500	4,060
3,000 n at 6 m	500	3,345
3,000 n at 12 m	400 or 500	3,535 to 3,795
Site 28		
10,000 n at 6 m	500	3,825
10,000 n at 12 m	400	3,770
7,000 n at 6 m	400	3,605
7,000 n at 12 m	400	4,255
5,000 n at 6 m	400	3,610
5,000 n at 12 m	400	3,695
3,000 n at 6 m	400	3,255
3,000 n at 12 m	400	3,825
Site 23		
10,000 n at 6 m	400	2,450
10,000 n at 12 m	400	2,355
7,000 n at 6 m	400	2,390
7,000 n at 12 m	400	2,290
5,000 n at 6 m	400	2,470
5,000 n at 12 m	400	2,395
3,000 n at 6 m	400	2,280
3,000 n at 12 m	400	2,420

1. The dollar figures reported are approximate for the treatment density shown. Refer to Appendix I for more accurate figures.
2. n = naturally established stand
   p = planted stand

3.4.2 Northern Interior Recommendations

White Spruce - General Recommendations:

- Densities of 1,600 stems per hectare or more can be considered for spacing.
- Low initial densities and poor site have the lowest priority, high initial densities and good site have the highest priority.
- A post-spacing density of 500 stems per hectare yields the greatest financial return.
- Spacing is financially feasible for good site, appears to be financially feasible for medium site given current spacing costs, but may be cost constrained on poor site.

White Spruce - Specific Recommendations:

Regime [2] & Site Index	Treatment Density (stems/ha)	Cost Limitations [1] ($/ha)
Site 21		
10,000 n at 4 m	500	1,690
7,000 n at 4 m	500	1,460
5,000 n at 4 m	500	1,480
1,600 p at 4 m	500	1,215
Site 17		
10,000 n at 4 m	500	1,000
7,000 n at 4 m	500	905
5,000 n at 4 m	500	840
1,600 p at 4 m	500	710
Site 13		
10,000 n at 4 m	500	480
7,000 n at 4 m	500	435
5,000 n at 4 m	500	375
1,600 p at 4 m	500	310

1. The dollar figures reported are approximate for the treatment density shown. Refer to Appendix I for more accurate figures.
2. n = naturally established stand
   p = planted stand

Northern Interior Lodgepole Pine - General Recommendations:

- Good and medium site offer a variety of spacing opportunities. Poor site appears to be cost constrained.
- Densities of 1,600 stems per hectare or more on good or medium site can be considered for spacing.
- Financially there is a significant difference between spacing at 4 m, 10 m and 17 m; in general the best opportunities are at 4 m.
- On good and medium site some opportunities exist for spacing at 10 m, but in many cases spacing costs will be a limiting factor. Spacing at 17 m appears to be cost constrained.

Northern Interior Lodgepole Pine - Specific Recommendations:

Regime [2] & Site Index	Treatment Density (stems/ha)	Cost Limitations [1] ($/ha)
Site 22		
20,000 n at 4 m	500	1,675
20,000 n at 10 m	500	480
10,000 n at 4 m	500	1,690
10,000 n at 10 m	500	695
10,000 n at 17 m	800	320
7,000 n at 4 m	500	1,495
7,000 n at 10 m	500	770
7,000 n at 17 m	500	180
5,000 n at 4 m	500 or 600	1,155 to 1,225
5,000 n at 10 m	500	1,210
5,000 n at 17 m	500	415
3,000 n at 4 m	500	1,015
1,600 p at 4 m	500	1,150
Site 18		
20,000 n at 4 m	500	800
20,000 n at 10 m	600 to 1000	240
10,000 n at 4 m	500	790
10,000 n at 10 m	800	335
10,000 n at 17 m	1400	270
7,000 n at 4 m	500 or 600	575 to 630
7,000 n at 10 m	500 or 600	335 to 355
7,000 n at 17 m	1400	315
5,000 n at 4 m	500	535
5,000 n at 10 m	500	470
5,000 n at 17 m	800 to 1200	155 to 180
3,000 n at 4 m	500	445
1,600 p at 4 m	400 or 500	485 to 560
Site 14		
20,000 n at 4 m	500	290
20,000 n at 10 m	n/a	Any cost limiting
10,000 n at 4 m	500 to 800	210 to 240
10,000 n at 10 m	n/a	Any cost limiting
10,000 n at 17 m	n/a	Any cost limiting
7,000 n at 4 m	500 to 800	190 to 210
7,000 n at 10 m	n/a	Any cost limiting
7,000 n at 17 m	n/a	Any cost limiting
5,000 n at 4 m	500 to 1000	170
5,000 n at 10 m	500 to 800	195 to 200
5,000 n at 17 m	1400 to 1600	245 to 280
3,000 n at 4 m	600	135
1,600 p at 4 m	500	120

1. The dollar figures reported are approximate for the treatment density shown. Refer to Appendix I for more accurate figures.
2. n = naturally established stand
   p = planted stand

Northern Interior Hemlock - General Recommendations:

- Densities of 5,000 stems per hectare or more can be considered for spacing.
- Good site, regardless of initial density, has the highest priority for spacing. Poor site, regardless of initial density, has the lowest priority.
- The greatest financial return from spacing Northern Interior hemlock occurs at leave densities of 500 or 600 stems per hectare on good and medium site, and 600 or 700 stems per hectare on poor site.
- Spacing is financially feasible for good site, may be financially feasible for medium site depending on spacing costs, but is likely to be cost constrained on poor site.

Northern Interior Hemlock - Specific Recommendations:

Regime [2] & Site Index	Treatment Density (stems/ha)	Cost Limitations [1] ($/ha)
Site 20		
10,000 n at 6 m	500 or 600	1,330 to 1,400
7,000 n at 7 m	500 or 600	1,245 to 1,325
5,000 n at 6 m	500 or 600	1,260 to 1,340
Site 16		
10,000 n at 6 m	500	725
7,000 n at 6 m	500 or 600	580 to 625
5,000 n at 6 m	500	710
Site 12		
10,000 n at 6 m	600 or 700	225 to 230
7,000 n at 6 m	700	215
5,000 n at 6 m	500	225

1. The dollar figures reported are approximate for the treatment density shown. Refer to Appendix I for more accurate figures.
2. n = naturally established stand
   p = planted stand

3.4.3 Southern Interior Recommendations

White or Engelmann Spruce - General Recommendations:

- Densities of 1,600 stems per hectare or more can be considered for spacing.
- Low initial densities and poor site have the lowest priority, high initial densities and good site have the highest priority.
- A post-spacing density of 500 stems per hectare yields the greatest financial return.
- Spacing is financially feasible for good site, appears to be financially feasible for medium site given current spacing costs, but may be cost constrained on poor site.

White or Engelmann Spruce - Specific Recommendations:

Regime [2] & Site Index	Treatment Density (stems/ha)	Cost Limitations [1] ($/ha)
Site 21		
10,000 n at 4 m	500	1,735
7,000 n at 4 m	500	1,495
5,000 n at 4 m	500	1,545
1,600 p at 4 m	500	1,265
Site 17		
10,000 n at 4 m	500	980
7,000 n at 4 m	500	915
5,000 n at 4 m	500	845
1,600 n at 4 m	500	715
Site 13		
10,000 n at 4 m	500	460
7,000 n at 4 m	500	425
5,000 n at 4 m	500	370
1,600 p at 4 m	500	320

1. The dollar figures reported are approximate for the treatment density shown. Refer to Appendix I for more accurate figures.
2. n = naturally established stand
   p = planted stand

Interior Douglas-fir - General Recommendations:

- Densities of 5,000 stems per hectare or more can be considered for spacing.
- Regardless of initial density, good and medium sites have a high priority for spacing. Medium site stands when spaced respond with a relatively large increase in average stand diameter. While stands on poor site respond well, average stand diameter is not sufficient to produce much in the way of large logs that provide higher prices, and hence spacing poor site has a much lower priority.
- A post-spacing density of 500 stems per hectare yields the greatest financial return.
- Spacing is financially feasible on good and medium site, but may be cost constrained on poor site.

Interior Douglas-fir - Specific Recommendations:

Regime [2] & Site Index	Treatment Density (stems/ha)	Cost Limitations [1] ($/ha)
Site 25		
10,000 n at 4 m	500	2,510
7,000 n at 4 m	500	2,260
5,000 n at 4 m	500	2,160
Site 21		
10,000 n at 4 m	500	1,465
7,000 n at 4 m	500	1,285
5,000 n at 4 m	500	1,240
Site 16		
10,000 n at 4 m	500	420
7,000 n at 4 m	500	425
5,000 n at 4 m	500	385

1. The dollar figures reported are approximate for the treatment density shown. Refer to Appendix I for more accurate figures.
2. n = naturally established stand
   p = planted stand

Southern Interior Lodgepole Pine - General Recommendations:

- Good and medium sites offer a variety of spacing opportunities. Poor site appears to be cost constrained.
- Densities of 1,600 stems per hectare or more on good or medium site can be considered for spacing.
- Financially there is a significant difference between spacing at 4 m, 10 m and 17 m; in general the best opportunities are at 4 m.
- On good and medium site some opportunities exist for spacing at 10 m, but in many cases spacing costs will be a limiting factor. Spacing at 17 m appears to be cost constrained.

Southern Interior Lodgepole Pine - Specific Recommendations:

Regime [2] & Site Index	Treatment Density (stems/ha)	Cost Limitations [1] ($/ha)
Site 22		
20,000 n at 4 m	500	1,530
20,000 n at 10 m	500	460
10,000 n at 4 m	500	1,530
10,000 n at 10 m	500 or 600	560 to 635
10,000 n at 17 m	800	390
7,000 n at 4 m	500	1,330
7,000 n at 10 m	500	655
7,000 n at 17 m	1600	165
5,000 n at 4 m	500 or 600	1,005 to 1,065
5,000 n at 10 m	500	1,040
5,000 n at 17 m	500 to 1200	185 to 245
3,000 n at 4 m	500	855
1,600 p at 4 m	500	995
Site 18		
20,000 n at 4 m	500	755
20,000 n at 10 m	600 to 1000	225 to 240
10,000 n at 4 m	500	720
10,000 n at 10 m	800	350
10,000 n at 17 m	1400 to 1600	225 to 235
7,000 n at 4 m	500 or 600	565 to 610
7,000 n at 10 m	500 or 600	340
7,000 n at 17 m	800 to 1600	220 to 290
5,000 n at 4 m	500	515
5,000 n at 10 m	500	465
5,000 n at 17 m	800 to 1200	190 to 220
3,000 n at 4 m	500	415
1,600 p at 4 m	400 or 500	420 to 495
Site 14		
20,000 n at 4 m	500	285
20,000 n at 10 m	n/a	Any cost limiting
10,000 n at 4 m	500 to 800	215 to 240
10,000 n at 10 m	n/a	Any cost limiting
10,000 n at 17 m	n/a	Any cost limiting
7,000 n at 4 m	700	210
7,000 n at 10 m	n/a	Any cost limiting
7,000 n at 17 m	n/a	Any cost limiting
5,000 n at 4 m	700	175
5,000 n at 10 m	500 to 800	175 to 190
5,000 n at 17 m	1600 to 2100	145 to 170
3,000 n at 4 m	600	130
1,600 p at 4 m	500	115

1. The dollar figures reported are approximate for the treatment density shown. Refer to Appendix I for more accurate figures.
2. n = naturally established stand
   p = planted stand

3.5 Other Factors Affecting Spacing Decisions

In addition to timber yields and net revenues earned from juvenile spacing, there are a number of other factors that must be considered before finalizing a decision on juvenile spacing including spacing costs, pests, biodiversity, AAC shortfalls, jobs and social welfare, thinning, pruning, and fertilization. These factors were not incorporated directly into the financial tables or in a decision matrix because:

- there were insufficient data to quantify impacts (pests/biodiversity)
- impacts are determined at a regional or provincial level not the stand level (AAC, jobs and social welfare)
- the variable is sensitive to too many changing factors to make average values in a table meaningful (spacing costs)
- the variable is only peripherally associated with spacing (thinning, pruning, fertilization), or inclusion would make the tables too complicated (spacing costs).

These factors do, however, have an important bearing on spacing decisions and the principal concepts are, therefore, discussed in the following sections.

3.5.1 Juvenile Spacing Costs

As discussed in section 3.2 and 3.3, spacing costs are estimated by the project manager who tries to correlate historic costs and conditions with conditions in the stands planned for spacing. A number of factors influence spacing costs:

- number and experience of spacing contractors bidding on the project
- road construction costs and other access constraints
- size of contract or program
- size of individual blocks
- snag falling requirements
- stand density
- tree size
- slash
- slope
- special clauses such as incorporation of biodiversity guidelines, pest removal, protection requirements such as rearranging or disposing of spacing slash, buffers etc.

The impact of each of these factors is self-evident. Where costs exceed net present value, other decision variables must provide the manager with a solid rationale for proceeding with the program. Potential reasons are discussed below.

3.5.2 Pests

Pest impacts are an important consideration in determining if and how a stand should be spaced. *Spacing can both increase and decrease the risk of pest attack.* This section briefly summarizes impacts and spacing strategies for the tree species and associated pests addressed in these guidelines.

Pests which could influence juvenile spacing practices include:

Lodgepole Pine	Interior Spruce	Western Hemlock	Douglas-fir
• root rots - *Armillaria* - *tomentosus* • dwarf mistletoe • blister rusts - *camandra* - *stalactiform* • western gall rust • leader weevil • root collar weevil • squirrels • porcupine • hares	• leader weevil • root rots - *Armillaria* - *tomentosus* • porcupine	• dwarf mistletoe • *Annosus* root rot • *Armillaria* root rot • porcupine	• root rots - *Armillaria* - *Phellinus* - black stain • squirrels (interior) • porcupine (interior)

With respect to spacing strategies, there are several general guiding concepts:

1 - incidence levels in the stand of interest should be obtained through ground surveys although useful information on the probability of attack can also be inferred for some pests from hazard rating maps.

2 - risk of attack is dependent on habitat and pest populations in surrounding areas.

3 - resistance to pest attack is not necessarily related to tree vigor. Some pests, such as squirrels and other small mammals, may actually be attracted by vigorous, nutrient rich trees (Sullivan 1984). Conversely, the resistance to pests which the tree combats with physiological defenses, may be reduced with decreasing tree vigor. With still other pests, resistance may be unrelated to tree vigor and more a function of tree size (mistletoes) or genetics (rusts) (Van der Kamp 1984).

4 - leaving higher densities to counteract the impact of pest attack is not always appropriate. Errico (1989) states, for example, that adjusting lodgepole pine spacing standards for pest damage is not warranted in B.C. He concludes that, for pests attacking lodgepole pine, the likelihood of specific levels of damage is unknown because local population dynamics are largely unknown. He further emphasizes that the loss in yield with prescribed density increases up to 1600 stems/ha will outweigh pest impact. He bases his conclusion in part on the idea that pest attack in overstocked stands will leave some understocked holes and the rest overstocked. Attack in spaced stands would also result in some holes but growth would be closer to optimum in stocked areas.

5 - favouring resistant tree species in and immediately adjacent to areas affected by pests during spacing is often the most cost effective method for reducing pest impact.

Pest specific impacts and strategies that might be employed in juvenile spacing are discussed below by pest.

Mistletoes

Mistletoes cause serious growth loss and mortality in pine, hemlock, and western larch. Infection on regeneration under 10 years old is uncommon, purportedly because such trees represent very small targets for mistletoe seed (Van der Kamp and Hawksworth 1984). Because rates of spread are very slow (0.5 m/yr) (Hawksworth and Johnson 1989), the most effective control is to minimize infection in young stands.

Low to moderate levels of mistletoe in a stand may increase the priority of spacing since spacing could be used to:

- fall infected regeneration
- remove infected residuals
- select non-susceptible host species along stand margins when adjacent stands are infected.

Caution should be exercised, however, since it is usually very difficult to detect mistletoe symptoms on younger trees (Van der Kamp 1984). Hawksworth & Johnson (1989) also caution that sanitation spacing is not likely to be practical when more than 40% of the stand is infected.

Rusts

Mortality and growth losses are the principal forms of damage resulting from stem rusts although none of the naturally occurring rusts will completely prevent development of a merchantable stand (Lowe and Ziller 1977). Severe damage by rusts is typically limited to certain restricted ecological conditions, however, where stocking levels are deliberately kept low, mortality can become significant (Van der Kamp and Hawksworth 1984). Most sources recommend leaving densities following spacing which are 20 - 30% higher than target stocking levels to compensate for mortality. Wood (1987) suggests that delaying spacing until the crown is 2 - 3 meters above the ground will help reduce infections of camandra and stalactiform rust since new infections occur via the needles. Lowe and Ziller (1977) feel that incidence levels above 40% make juvenile spacing impractical.

With low incidence levels, it has been suggested that the priority for spacing may be increased because of the opportunity to remove infected individuals. This has not proven effective however, in operational trials (Endacott, pers. comm. 1991) because of erratic distribution of infections, the large source of innoculum in adjacent areas, and difficulty in detecting infections. Detection is considerably enhanced if spacing can be conducted in early summer (June) when white blisters filled with orange-yellow aeciospores break through the bark of cankers making them much more visible. In stands with higher incidence levels, the priority for spacing is probably lower than for an uninfected stand.

Root Rots

The root rots of concern in juvenile spacing operations are *Armillaria ostoyae, Phellinus weirii, Inonotus tomentosus, Heterobasidion annosum, and Verticicladiella wagenerii.* These pathogens enter a tree through exposed scars, insects vectors and/or root contact. Once established, they can spread to surrounding trees via root to stump or root to root transmission. Except for black stain root disease (*Verticicladiella*) the root rots can survive in dead stumps and roots for many years following death of the tree. Damage is a progressive reduction in tree vigor and growth with few of the trees infected at time of spacing likely to survive until rotation age.

In most stands, there will be no obvious evidence of root rot when the stands reach spacing age (*Armillaria* is an exception to this rule). If moderately high incidence levels (>10%) are detected, most sources recommend against spacing (Wood 1987, Morrison *et al.* 1986, Morrison 1981, Wallis 1976). At best, spacing will only delay the spread of fungus and many trees intended for the final crop will be killed before rotation (Morrison 1981, Wallis 1976). Where root rot pockets are sporadic and easily identified, it may be possible to exclude them [and an appropriate buffer (~4 m)] from spacing. In mixed species stands, favouring less susceptible species is also possible.

In areas where annosus root disease is found, it is recommended that spacing be conducted before trees reach 10 cm in diameter and that high stumps be left (Wood 1987, Morrison 1981). The objective is to allow the trees to rot before the disease can spread through the stump and into surrounding tree roots. An alternative is to treat the cut stumps with borax or zinc sulfate to prevent spore colonization. Whenever possible, favour species other than amabilis fir, Sitka spruce, and western hemlock.

In areas where black stain root disease is the problem, spacing may be slightly more advisable since *Verticicladiella* exhibits very poor survival in dead roots. Juvenile spacing can, however, greatly increase the incidence and impact of this disease (Heppner pers. comm. 1992). Vectors (*Hylastes nigrinus*) colonize and build up in the spacing stumps, colonized stumps become infected, and the disease is transmitted to crop trees via root grafts. If spacing is conducted, it should be scheduled after June when the vector has completed its flight. In general, however, the presence of moderate to high levels of root rot makes juvenile spacing a very low priority.

Weevils

Weevils of concern include spruce and pine leader weevils (*Pissodes strobi* and *P. terminalus*) and root collar weevil (*Hylobius warrenii*). Leader weevil incidence in pine is sporadic and generally not considered to be significant. Leader weevil damage on Engleman, white, and Sitka spruce, however, has been very extensive in some areas of the province. The weevil attacks the terminal, lays its eggs, and the developing larvae girdle and kill the current and previous year's leader. Attack can result in crooked or forked stems, possibly resulting in poor log quality. Recent evidence suggests that damage is more likely to be significant with repeated attacks (Tim Ebata pers. comm. 1992). After age 30, very little weevil attack occurs and most trees are no longer susceptible to attack (Amman and Safranyik 1984).

Removal of poorly spaced, damaged stems during spacing may help improve stand quality but will not prevent further attacks. Alfaro and Omule (1990) suggest that less defect will occur in denser stands (~1600 stems/ha), however, in general, juvenile spacing should not be conducted in areas of high weevil hazard.

The other major weevil affecting second growth crops is root collar weevil. Root collar weevil is frequent in low elevation pine sites with thick duff (Cerezke 1971 cited in Amman and Safranyik 1984). Spruce is also susceptible but incidence is generally lower than for pine. Weevils can be found on trees of all ages but significant damage is restricted to trees less than 20 years of age with the highest mortality in 5 - 10 year old stands. In natural stands mortality rarely exceeds 10% (Cerezke 1974, Tim Ebata pers. comm. 1992). Because damage in older stands is minimal, the best strategy for spacing is to delay it beyond 20 years of age by which point all significant mortality should have occurred. Presence of root collar weevil then, reduces spacing priority in that treatment is deferred.

Hares, Squirrels, and Porcupine

Squirrel and porcupine damage has been extensive in localized areas on sapling and pole sized stems for most species in the Interior of B.C. Serious snowshoe hare damage is restricted to lodgepole pine and Douglas-fir stems less than 6 cm in diameter (Sullivan 1990, Wood 1987, Sullivan 1984). Spacing of these small diameter stands should be timed to correspond to low hare populations (peak populations occur every 9 - 10 years) or deferred until the stand grows beyond 6 cm of diameter (Sullivan 1984).

Squirrel and porcupine damage is caused when the animals feed on the stem cambium girdling or nearly girdling the tree. Semi-girdling suppresses diameter growth and complete girdling will kill the tree. Neither squirrel nor porcupine populations seem to have consistent cycles, however, there is some evidence that squirrel abundance increases after a substantial cone crop (Sullivan, 1990). Porcupine populations may be related to habitat changes and trends in predator populations.

Silviculture strategies to reduce squirrel and porcupine damage at the spacing stage recommended by Sullivan (1990) are:

Squirrel: in high hazard areas prescribe lower leave densities and larger spacing blocks (>100 ha) to encourage predator avoidance behavior and avoid small blocks of unspaced stands within extensive areas of spacing.

Porcupine: leave as crop trees less preferred species such as amabilis fir and western red cedar and prescribe leave densities below 1000 stems/ha to encourage predator avoidance behavior.

Presence of moderate levels of squirrel or porcupine damage (>10%) during the spacing survey will mean the stand should be assigned a much lower priority. In the Prince Rupert Forest Region the current recommendation is that stands should not be considered for spacing if there is any evidence of porcupine activity in or near the stand (Harrison pers. comm. 1992).

3.5.3 Annual Allowable Cut Shortfalls

Timber supply shortfalls have been forecast within a few decades for a number of TSA's in the province (Kivari pers. comm. 1992). Ameliorating these shortfalls by making wood available earlier through juvenile spacing may be an option. Table 16 shows how density control influences the time to achieve specific target diameters and volume.

It is clear from Table 16 that spacing has a relatively modest influence on the time to achieve a target volume. In fact, spacing a stand can even result in a delay in reaching target volume and will not, therefore, change the overall volume of wood available. What spacing will do is allow the estate manager to make a reduced volume of larger diameter wood available earlier. The greatest gains in time are made with pine, however, substantial gains can also be made with other species ranging from 89 to 181 years on poor sites, 55 to 85 years on medium sites, and 36 to 50 years on good sites.

By manipulating stand density, the manager can, within limits, control when timber is available. The example with pine in Table 17 below illustrates this point. It will take 137 years for a dense stand (10,000 stems/ha) to reach 25 cm dbh on site index 18 if it is not spaced, 108 years if spaced at 4 m site height to 1600 stems/ha, and 51 years if spaced at 4 m site height to 600 stems/ha.

TABLE 16. Maximum reductions in rotation length resulting from juvenile spacing (spacing conducted at 4 m height for interior species and 6 m height for coastal species, volumes are merchantable using a 17.5 cm minimum dbh for hemlock and Douglas-fir and 12.5 cm for the other species).

Interior (Initial density = 10,000 stem/ha)

Species	Pl			Sx			Hw			Fd		
SI	14	18	22	13	17	21	12	16	20	16	21	25
Years to 25 cm dbh												
• Control	>295	137	87	178	129	98	289	152	104	>200	125	90
• Spaced to 700 sph	79	56	43	93	70	57	108	70	54	87	60	48
Difference	>216	81	44	85	59	41	181	82	50	>113	85	42
Years to 350 m3/ha												
• Control	161	95	66	123	92	72	128	82	62	129	82	62
• Spaced to 1600 sph	138	85	61	115	86	68	137	87	65	121	77	60
Difference	23	10	5	8	6	4	-9	-5	-3	8	5	2

Coast (Initial density = Fd 4440 sph, Hw 10,000sph)

Species	Fd			Hw		
SI	25	30	35	23	28	33
Years to 40 cm dbh						
• Control	192	111	80	160	111	84
• Spaced 400 sph	75	56	44	71	55	44
Difference	117	55	36	89	56	40
Years to 600 m3/ha						
• Control	99	69	54	76	58	46
• Spaced 1100 sph	98	69	54	80	60	48
Difference	1	0	0	-4	-2	-2

Note that the spacing densities chosen provide the maximum possible reduction in time to achieve the stated targets, relative to the same stands if not spaced.

TABLE 17. Age at which average stand diameter reaches 25 cm (note that the control stand is grown from 10,000 stems/ha initial density with no repression).

Site Index	14			18			22		
Regime (stems/ha)	Spaced	Control	*Difference*	Spaced	Control	*Difference*	Spaced	Control	*Difference*
3000	265	295	*30*	129	137	*8*	83	87	*4*
2100	227	295	*68*	119	137	*18*	78	87	*9*
1600	195	295	*100*	108	137	*29*	73	87	*14*
1100	128	295	*167*	81	137	*56*	59	87	*28*
900	100	295	*195*	67	137	*70*	50	87	*37*
600	72	295	*223*	51	137	*86*	40	87	*47*

Manipulating stand density to alleviate timber supply short falls, however, does come at a cost:

- fiber flow in the long run will be reduced since MAI will be lower in the spaced stand, particularly at low densities (this would mean a reduction in the long run sustained yield) and
- deviation from the optimum financial rotation will, of course, result in a reduced net present value.

Whether the timing of wood supply should take precedence over maximizing financial return or mean annual increment can only be determined through careful forest estate planning and answering questions such as:

- given expected future mill capacity, what are projected timber supply deficits by year?
- what are the projected areas by site class and year available for density control and to what extent do they ameliorate timber supply shortfalls?
- what is the economic impact on the community at the point in time supply deficits occur?
- what expense or reduced rate of return is government/industry willing to incur in order to maintain jobs and community stability?
- what is the expected short and long term effect on employment if supply deficits occur?

3.5.4 Jobs and Social Welfare

Wood supply deficits in the future could lead to fewer direct jobs (from forest management and silviculture, harvesting and timber transport, manufacturing and marketing), fewer indirect jobs (from spin-off industries providing supplies and equipment), and fewer induced jobs (service sector). The impact on forest dependent communities would be declining economic activity, unemployment, a reduced tax base, and a possible decline in population (MoF, 1990).

In a recent study on community dependency the province was divided into seven regions (excluding Vancouver - Fraser Valley - Sunshine Coast). The aggregate community data for these regions gives some insight into community dependance on forestry outside the lower mainland.

TABLE 18. Community dependency on the forest sector. (Source: Forest Resource Commission Report, 1992).

Sectors	Numbers of Areas	Percent
Forestry Dominated	21	38
Forestry & One Other	13	24
Forestry & Two or More Other	8	14
Non-Forestry Dominated	13	24
	55	100

Forestry was the dominant *source of income* for the community 38 percent of the time and was responsible for at least one-half of the income 62 percent of the time. Over 75 percent of all the communities outside the lower mainland depend on forestry as a major source of income.

Spacing, a major component of intensive forest management, might assist some communities in maintaining their forestry incomes by preventing timber supply shortfalls and providing short term employment. Spacing is labour intensive. Depending on spacing difficulty (productivity) one person-year of employment will be created for every 50 - 175 hectares spaced. Because the work can be conducted in the winter, it could reduce off-season employment problems for silviculture workers.

Where an investment in spacing provides increased net revenues, and where the return for the use of public funds exceeds other opportunities, society will benefit from increased income and job creation. The MoF uses a real rate of return of 4 percent as a guide for silviculture investments. Thus, forestry investments yielding 4 percent or more can be categorized as a sound public investment. However, in some areas of the province, in some circumstances, a 4 percent return may not be possible. In these cases, *failing any other alternatives that would yield 4 percent,* spacing could still be considered to be an option. Maintenance of the economy at a lower rate of return is better then letting the economy regress further.

It may also be appropriate in such circumstances to promote the training and use of the local unemployed. Wages for spacing work would be lower in areas of high unemployment and this should offset lower productivity expected during training periods. In conducting this type of program, however, it must be remembered that if no new value is created through spacing, government may be incurring debt today which must be paid from other sources by future generations.

3.5.5 Biodiversity

Biological diversity (biodiversity) in the context of juvenile spacing, refers to maintenance of diverse horizontal and vertical structure as well as plant and wildlife species diversity. The management of biodiversity occurs on 3 levels; the management unit level (TSA), landscape or watershed level, and the stand level. Successful management ensures adequate strategies at all 3 levels. The impact of juvenile spacing is primarily at the stand level.

Specific practices recommended by the B.C. Ministry of Forests and Ministry of Environment (Klenner 1991, Stevens 1991) to maintain biodiversity through spacing operations include:

- maintain groups of safe snags, possibly creating new snags by girdling some trees.
- maintain some hardwoods (e.g. 10/ha).
- create a mosaic of tree sizes and crown closure by spacing to a variety of densities or entering the stand at different ages (provides suitable forage areas adjacent to thermal or escape cover).

- leave some gaps or very wide spacings to enhance forage habitat.
- maintain tree species diversity - do not favour a single species to the exclusion of others.
- remove slash from wildlife travel corridors.
- leave untreated buffers along special habitats such as riparian areas, nesting or calving areas, etc.

The general goal is to recognize inherent diversity and then conduct spacing such that the removal of essential features is minimized. This may result in increased spacing costs making spacing less attractive and, therefore, lower priority. Conversely, the estate manager may attribute special importance to maintenance of a certain level of biodiversity and this may supersede cost considerations. Finally, juvenile spacing can enhance structural diversity beyond what would occur in the natural stand through the creation of openings and a range of densities. If the achievement of this kind of structural diversity is a management objective, spacing in these stands may have a higher priority.

3.5.6 Commercial Thinning

The two principal reasons for commercial thinning are:

- to capture mortality before it occurs thus increasing total cumulative yield
- to provide a financial return early in the rotation that might otherwise be lost at the time of final harvest because of mortality and decreased stem size.

Commercial thinning is one method of increasing long run sustained yield and potentially reducing timber supply shortfalls. When commercial thinning is planned, more of the site's potential can be used by maintaining a denser stand early in the rotation. This is possible only if:

- these extra trees are removed before competition results in significant diameter growth losses and mortality,

- the diameter of the stand at the point at which significant growth loss begins is large enough to produce a merchantable product(s), and

- the volume removed is sufficient to pay for the cost of thinning.

If a stand is juvenile spaced to the density which will provide the greatest financial return at rotation (as discussed in this report), it is likely that there will be insufficient volume or density to conduct a commercial thinning. If a commercial thinning is planned, the target leave density for the juvenile spacing should be increased. The increase is likely less than what would normally be thought suitable, however, since stem size is so critical in determining stand value. If, for example, 500 stems/ha would be left with no thinning planned, then 800 or 900 stems/ha after spacing might be the right order of magnitude where a subsequent thinning was planned. Unfortunately, there are insufficient data to support any concrete guideline. It is recommended, therefore, that further analysis be conducted.

3.5.7 Pruning & Fertilization

The decision to space is not dependent on pruning or fertilization rather, the decision to prune or fertilize in dense stands will depend on whether or not spacing is planned for the area. The basic concept is that these two activities should not be conducted prior to spacing since the treatment will be wasted on all trees which are subsequently felled during spacing. This would not be the case for pruning if only crop trees were pruned before spacing.

Periodic thinning may be required to maintain stands in a stocking range that is responsive to fertilizer (Debell 1981). Fertilizing stands with too may stems simply speeds competition induced mortality and results in little value gain (Richard *et al.* 1986). Neither fertilization nor pruning should be restricted to spaced stands, however. These treatments could be conducted in any stand with the appropriate size/density range provided that there is a net financial return.

3.5.8 Logging Difficulty and Haul Distance

All of the DNR's in Appendix I were tested to see what variation would occur if an easy logging/short haul situation and a difficult logging/long haul situation were considered in addition to the average logging/medium hauling situation.

With very few exceptions there was less than 10 percent variation in DNR from the average. This is because most of the value attributable to spacing relates to the higher market price obtainable for large logs (i.e. the value of a m^3 of large logs versus the value of a m^3 of small or unspaced stand logs). Very little value relates to logging or hauling costs as these costs are only marginally cheaper for the spaced stand than for the unspaced stand.

Typical examples of the variation in the DNR's in Appendix I for the easy logging/short haul situation and the difficult logging/long haul situation are shown in Table 19. Given the low magnitude of the variation, the decision to space could be made by considering only the average logging difficulty and haul distance.

The use of the average situation will give the correct answer for both the decision to space or not to space as well as ranking stands as to priority with degree of accuracy that is compatible with the data and analysis in this report.

The decision to space or not to space should be based on significant differences (e.g. the effect of site index, which can easily be seen in Table 19). Consideration should not focus on the situation where the DNR's and the spacing cost are of a similar order of magnitude. It does not matter if the benefit-cost ratio for a particular situation is 1.05 (a very low priority) or 0.95 (no priority) as long as there is a significant number of situations or options that have a ratio of 1.1 or greater.

In Table 19 it can be seen that the degree of logging difficulty and the haul distance can increase or decrease the DNR's. This can cause considerable concern to those who are not familiar with the complexities of the situation being evaluated. Under particular circumstances the difficult logging/long haul situation can provide more spacing value (higher DNR). This result may occur when the spaced stand provides significantly larger stems or logs than the unspaced stand and significantly reduces logging costs. Also, if spacing increases the stem size to such a degree that a lesser volume of large logs is worth more than a larger volume of small logs, the situation arises where logging and hauling less volume decreases total costs and increases the DNR value.

Note that comparing the value of a spaced stand in one situation (i.e. easy logging/short haul) to the value of a spaced stand in another situation (i.e. difficult logging/long haul) is not really appropriate without considering spacing costs. Spacing costs will vary between stands and are likely to be higher for distant sites and difficult terrain. Thus, the three different values shown in Table 19 should be considered with three different spacing costs in order to determine the feasibility of each situation and the appropriate benefit-cost ratio for each situation.

TABLE 19. Variation in Appendix I DNR's attributable to logging difficulty and haul distance.

Regime and Treatment	Easy Log/ Short Haul	Avg. Log/ Med. Haul	Diff. Log/ Long Haul
Coast			
Douglas-fir, 4444 to 500 at 6 m			
Site 35	2929	2844	2663
Site 30	2887	2879	2792
Site 25	1508	1504	1494
Coastal Hemlock, 5000 to 500 at 6 m			
Site 33	3990	3939	3683
Site 28	3287	3243	3124
Site 23	2034	2063	2116
Northern Interior			
White Spruce, 1600 planted to 500 at 4 m			
Site 21	1186	1215	1256
Site 17	702	712	728
Site 13	300	312	330
Interior Hemlock, 7000 to 500 at 6 m			
Site 20	1331	1326	1310
Site 16	626	626	634
Site 12	209	205	199
Southern Interior			
Lodgepole Pine, 10,000 to 500 at 4 m			
Site 22	1553	1528	1497
Site 18	702	722	715
Site 14	251	242	230
Douglas-fir, 5000 to 500 at 4 m			
Site 25	2151	2159	2167
Site 21	1217	1240	1277
Site 16	383	386	392

This report presents an analysis based on the concept of changing the value of a specific stand in a specific set of circumstances by spacing. The comparison is between spaced and unspaced for the same stand.

The interaction of various circumstances of stand location, logging chance and final harvest timber value can be complex. The concept that intensive forestry management practices can change the economics of wood supply merits further investigation.

3.6 Comments On Spacing Survey Procedures

Most of the basic stand information needed to use these guidelines can be obtained from the spacing survey procedures currently recommended by the Ministry of Forests. For more accurate and effective prescriptions, however, the MoF procedures should be enhanced in three ways:

1. distinguish between competing and non-competing trees.
2. measure site index during the survey.
3. describe density distribution.

Competing Trees

For the purposes of these guidelines, competing trees are both crop and non-crop species which are not well spaced, are in excess of the target density, and are some minimum height relative to leave trees. In the absence of better guidelines, the interim guidelines for countable trees developed by the joint MoF/licensee Lodgepole Pine Maximum Density Committee (1990) could be adopted. These guidelines state that a tree is only countable (providing a significant level of competition) when it is taller than the average height of regeneration which established in the eighth year after disturbance. The committee recommended that, for pine, the following heights be used as a cut-off on an interim basis until adequate height growth information could be collected.

Years Since Disturbance	Minimum Ht. to be Countable
0-7	N/A
8	5 cm
9	20 cm
10	30 cm
11	40 cm
12	50 cm
13	60 cm
14	70 cm
15	80 cm

When determining the density of the stand, in order to choose the appropriate financial table, only those trees which are actually significant competitors (countable) should be used.

Site Index

A second important modification of the survey procedures is to determine site index by treatment stratum during the survey. Site quality is the single most important variable driving yield. This would entail obtaining height and age measurements at a sufficient number of plots to have some confidence in the reliability of the data. There are two methods: measure total height and breast height age then look up the corresponding site index in published site index tables or, measure height growth of a specified number of internodes above breast height and use a growth intercept equation to calculate site index. Both methods have their limitations.

In juvenile stands, initial height growth can be heavily influenced by brush conditions and pests. Total height, then, may not accurately reflect potential height growth. When using this method, it is important to choose dominant trees that have no sign of pest damage.

Using the growth intercept method, height increment is measured above breast height where many of the problems with brush competition, frost damage, etc. have been surpassed. The limitation of the growth intercept method is that a localized equation to predict site index must be developed. An example for coastal Douglas-fir is Site Index = 10 + 32.7 x GI, where GI, the growth intercept, is the average of 5 years height growth above breast height measured in meters. This type of equation is not available for all species in all parts of the province.

If the spacing guidelines are used for openings already surveyed, and site index information was not provided, another very much inferior option, would be to determine site class from the forest cover map. Using Table 10 (see sec. 3.1.2) the mid-point of the class could be used as a rough approximation of site index.

Density Distribution

Surveyors must ensure that they have accurately accounted for density distribution. The yield on a site with an average density of 5000 stems/ha, for example, will be much different than yield on that same site when stocking was actually 55% 8000 stems/ha and 45% 1300 stems/ha. Roughly homogeneous areas of density should be typed out as separate strata and financial return calculated separately for each. Where strata are too small to be viable units on their own, an area-based, weighted average financial return could be calculated for the whole opening. If density units are unmappable complexes (very patchy distribution), there is no choice but to estimate the percent area in pre-defined density classes and then calculate an area-based weighted average density. This average density would be used to determine financial return.

Once the survey is completed, relevant site information can be used in the guidelines to determine:

- the maximum possible financial return from spacing
- whether the resulting increase in net present value will exceed the cost of spacing
- the appropriate leave density
- priorities between stands.

Of course, these decisions must be made in the context of management objectives and the other considerations discussed in section 3.5.

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APPENDIX I

DISCOUNTED NET REVENUE TABLES

Appendix 1 - Discounted Net Revenue (DNR) Tables

NORTHERN INTERIOR

Maximum dollar amount that can be spent per hectare to treat the regime to the specifications shown and yield a return of 4% real. Treatment at a cost lower than the amount shown will yield more than 4% real. Treatment at a cost higher than the amount shown will yield less than 4% real.

Minimum volume for a merchantable stand:

200 m3 per hectare at 12.5 (spruce 17.5) cm d.b.h. utilization.

Zero entries indicate that a 4% return cannot be attained by treatment at any cost.

Select the characteristics that most closely match the situation for the stand being considered for spacing (species, initial density, site, and height) and then consider the pertinent row showing the estimated outcomes (Rotation--MAI, Average stand diameter and Discounted Net Revenue) for a range of leave densities.

The highest DNR (after subtracting estimated spacing costs) is the best choice and presupposes that the indicated rotation will be used. The consequences of selecting a leave density other than the optimum is the difference between the two DNR's.

The tables can be used to:

1) select an appropriate leave density (including the discounted net revenue foregone if the optimum is not chosen)

2) determine if spacing is feasible (the DNR shown must exceed the anticipated cost of spacing)

3) determine a priority for spacing for the stand (i.e. an index number that can be used for comparative purposes, obtained by dividing the DNR number by the anticipated cost of spacing.

COAST - DOUGLAS FIR

Regime (Stems untreated)	Treatment (No. of stems after spacing)							
4,444 (Natural)	1100	1000	900	800	700	600	500	400
Site 35 at 6 m								
Rotation-MAI	90-11.3	90-11.3	90-11.4	90-11.3	80-11.5	80-11.4	70-11.0	70-10.5
Average Dia (cm)	46	47	48	48	46	48	48	52
Av. Log/Med. Haul	$ 261	655	1114	1058	1353	2105	2844	2991
Site 30 at 6 m								
Rotation-MAI	80-8.2	80-8.3	90-8.3	80-8.2	80-8.1	70-7.7	80-7.9	80-7.5
Average Dia (cm)	35	36	39	38	39	39	45	48
Av. Log/Med. Haul	$ 644	868	1005	1278	1529	1960	2879	3464
Site 25 at 6 m								
Rotation-MAI	70-5.6	70-5.5	70-5.4	80-5.5	80-5.4	80-5.3	80-5.1	80-4.6
Average Dia (cm)	27	28	29	32	34	36	38	41
Av. Log/Med. Haul	$ 412	495	579	734	1052	1301	1504	1801
Site 35 at 12 m								
Rotation-MAI	100-10.8	90-11.3	90-11.4	90-11.4	90-11.4	80-11.3	80-11.1	70-10.4
Average Dia (cm)	50	46	46	47	49	47	50	50
Av. Log/Med. Haul	$ 0	373	428	865	1425	2013	2618	3200
Site 30 at 12 m								
Rotation-MAI	100-8.1	80-8.2	90-8.2	80-8.1	80-8.1	80-7.5	80-7.7	90-7.6
Average Dia (cm)	38	34	38	37	38	40	43	49
Av. Log/Med. Haul	$ 285	556	919	1300	1538	2116	2766	3458
Site 25 at 12 m								
Rotation-MAI	70-5.4	70-5.4	70-5.3	90-5.5	90-5.4	80-5.1	70-4.6	80-4.6
Average Dia (cm)	26	27	28	33	34	34	34	39
Av. Log/Med. Haul	$ 433	568	688	852	1014	1354	1572	1971

COAST - DOUGLAS FIR

Regime (Stems untreated)	Treatment (No. of stems after spacing)							
2,500 (Planted)	1100	1000	900	800	700	600	500	400
Site 35 at 6 m								
Rotation-MAI	100-10.9	90-11.4	90-11.6	90-11.6	90-11.6	80-11.8	70-11.4	70-11.2
Average Dia (cm)	50	46	47	48	49	48	48	52
Av. Log/Med. Haul	$ 78	372	824	1218	1351	2426	3221	3523
Site 30 at 6 m								
Rotation-MAI	100-8.4	100-9.4	70-8.4	80-8.5	70-8.2	80-8.4	70-7.9	80-7.7
Average Dia (cm)	39	39	34	38	37	42	42	48
Av. Log/Med. Haul	$ 701	973	1182	1575	1824	2574	3018	3829
Site 25 at 6 m								
Rotation-MAI	70-5.7	70-5.7	70-5.6	90-5.8	80-5.6	80-5.6	70-5.1	80-4.9
Average Dia (cm)	27	28	29	34	34	36	36	42
Av. Log/Med. Haul	$ 425	524	608	805	1087	1374	1583	2073
Site 35 at 12 m								
Rotation-MAI	100-10.9	100-10.9	90-11.4	90-11.5	90-11.5	80-11.6	80-11.5	70-11.0
Average Dia (cm)	48	49	45	46	47	46	49	50
Av. Log/Med. Haul	$ 0	0	81	503	957	1764	2759	3709
Site 30 at 12 m								
Rotation-MAI	80-8.4	80-8.3	70-8.1	70-8.1	70-7.9	80-8.1	80-7.9	80-7.6
Average Dia (cm)	33	34	33	34	35	40	43	46
Av. Log/Med. Haul	$ 553	849	1103	1431	1637	2458	3153	3775
Site 25 at 12 m								
Rotation-MAI	70-5.5	70-5.5	70-5.5	90-5.6	70-5.3	80-5.3	70-4.8	80-4.8
Average Dia (cm)	27	27	28	33	31	34	34	39
Av. Log/Med. Haul	$ 592	592	720	878	1069	1403	1688	2072

COAST - DOUGLAS FIR

Regime (Stems untreated)	Treatment (No. of stems after spacing)				
1,200 (Planted)	800	700	600	500	400
Site 35 at 6 m					
Rotation-MAI	90-11.2	80-11.4	80-11.3	70-10.8	70-10.6
Average Dia (cm)	47	45	47	47	51
Av. Log/Med. Haul	$ 696	998	1718	2400	2983
Site 30 at 6 m					
Rotation-MAI	80-8.2	70-7.8	80-8.0	80-7.8	80-7.5
Average Dia (cm)	37	36	41	44	48
Av. Log/Med. Haul	$ 870	1084	1907	2383	3279
Site 25 at 6 m					
Rotation-MAI	80-5.5	80-5.3	80-5.2	80-5.0	90-4.8
Average Dia (cm)	32	33	35	38	43
Av. Log/Med. Haul	$ 352	468	747	1093	1353
Site 35 at 12 m					
Rotation-MAI	90-11.2	90-11.3	80-11.3	80-11.2	70-10.4
Average Dia (cm)	46	47	46	49	50
Av. Log/Med. Haul	$ 455	916	1687	2655	3309
Site 30 at 12 m					
Rotation-MAI	70-8.0	70-7.8	80-7.9	70-7.4	80-7.3
Average Dia (cm)	34	35	40	40	46
Av. Log/Med. Haul	$ 932	1126	1909	2433	3186
Site 25 at 12 m					
Rotation-MAI	70-5.4	70-5.2	80-5.2	80-5.0	80-4.6
Average Dia (cm)	29	31	34	37	39
Av. Log/Med. Haul	$ 275	508	812	1283	1461

COAST - HEMLOCK

Regime (Stems untreated)	Treatment (No. of stems after spacing)					
10,000	1100	1000	816	600	500	400
Site 33 at 6 m						
Rotation-MAI	90-15.2	90-15.3	90-15.3	80-15.1	70-14.5	70-14.0
Average Dia (cm)	46	47	48	48	48	53
Av. Log/Med. Haul	$ 1372	1798	2260	3361	4178	4190
Site 28 at 6 m						
Rotation-MAI	90-11.6	90-11.6	80-11.4	90-11.4	80-10.9	80-10.1
Average Dia (cm)	39	40	39	46	47	50
Av. Log/Med. Haul	$ 946	1229	1618	2838	3827	3750
Site 23 at 6 m						
Rotation-MAI	70-7.0	100-8.2	90-7.8	90-7.4	90-7.2	90-6.6
Average Dia (cm)	28	35	35	40	43	46
Av. Log/Med. Haul	$ 480	595	903	1697	2180	2454
Site 33 at 12 m						
Rotation-MAI	80-15.1	80-15.1	90-15.3	80-14.9	70-14.4	70-13.6
Average Dia (cm)	40	41	46	47	47	51
Av. Log/Med. Haul	$ 201	641	1577	3210	4232	4332
Site 28 at 12 m						
Rotation-MAI	80-11.0	80-11.0	90-11.0	80-10.5	90-10.5	80-9.6
Average Dia (cm)	34	35	40	41	47	47
Av. Log/Med. Haul	$ 258	562	1361	2386	3339	3771
Site 23 at 12 m						
Rotation-MAI	70-6.7	70-6.6	80-6.9	80-6.6	90-6.7	110-6.8
Average Dia (cm)	27	28	32	35	40	48
Av. Log/Med. Haul	$ 520	630	864	1395	1946	2354

COAST - HEMLOCK

Regime (Stems untreated)	Treatment (No. of stems after spacing)					
7,000	1100	1000	816	600	500	400
Site 33 at 6 m						
Rotation-MAI	90-15.2	90-15.2	90-15.2	80-14.9	70-14.5	70-13.9
Average Dia (cm)	46	47	48	48	48	53
Av. Log/Med. Haul	$ 1064	1488	1953	2944	3876	3877
Site 28 at 6 m						
Rotation-MAI	100-11.6	90-11.6	80-11.4	90-11.1	80-10.4	80-9.9
Average Dia (cm)	42	40	39	46	46	50
Av. Log/Med. Haul	$ 1029	1224	1616	2746	3262	3606
Site 23 at 6 m						
Rotation-MAI	70-6.9	100-8.2	100-8.1	90-7.4	90-7.1	100-6.9
Average Dia (cm)	28	35	37	40	42	48
Av. Log/Med. Haul	$ 411	531	839	1653	1897	2392
Site 33 at 12 m						
Rotation-MAI	80-15.1	80-15.1	80-14.9	80-14.5	80-13.9	70-13.1
Average Dia (cm)	40	41	43	46	49	49
Av. Log/Med. Haul	$ 0	301	1077	2203	2792	3425
Site 28 at 12 m						
Rotation-MAI	80-11.1	80-11.0	80-10.8	90-10.8	90-10.5	80-9.7
Average Dia (cm)	34	35	37	44	47	48
Av. Log/Med. Haul	$ 342	644	1241	2587	3448	4255
Site 23 at 12 m						
Rotation-MAI	70-6.8	70-6.7	80-7.0	90-7.2	90-6.8	110-6.8
Average Dia (cm)	27	28	32	38	40	48
Av. Log/Med. Haul	$ 464	563	824	1607	1921	2290

COAST - HEMLOCK

Regime (Stems untreated)	Treatment (No. of stems after spacing)					
5,000	1100	1000	816	600	500	400
Site 33 at 6 m						
Rotation-MAI	90-15.1	90-15.2	90-15.2	70-14.6	70-14.5	70-13.9
Average Dia (cm)	47	47	48	46	48	53
Av. Log/Med. Haul	$ 1499	1520	1985	3138	3939	3921
Site 28 at 6 m						
Rotation-MAI	100-11.5	90-11.5	80-11.3	90-11.4	80-10.7	80-10.1
Average Dia (cm)	42	40	39	46	46	50
Av. Log/Med. Haul	$ 863	1062	1450	2742	3243	3610
Site 23 at 6 m						
Rotation-MAI	100-8.1	100-8.1	90-7.7	90-7.5	100-7.4	90-6.7
Average Dia (cm)	35	35	35	40	45	46
Av. Log/Med. Haul	$ 545	541	850	1718	2063	2471
Site 33 at 12 m						
Rotation-MAI	80-15.0	80-15.3	80-15.4	80-15.4	70-14.5	70-13.7
Average Dia (cm)	41	42	44	48	47	51
Av. Log/Med. Haul	$ 323	807	1858	3785	4061	4120
Site 28 at 12 m						
Rotation-MAI	90-11.1	80-10.9	90-11.1	90-11.2	80-10.3	80-9.7
Average Dia (cm)	37	35	40	44	44	47
Av. Log/Med. Haul	$ 259	401	1241	2595	3103	3696
Site 23 at 12 m						
Rotation-MAI	70-6.7	70-6.6	80-7.0	90-7.2	90-6.8	110-7.0
Average Dia (cm)	27	27	32	38	40	48
Av. Log/Med. Haul	$ 466	443	849	1641	1933	2397

COAST - HEMLOCK

Regime (Stems untreated)	Treatment (No. of stems after spacing)					
3,000	1100	1000	816	600	500	400
Site 33 at 6 m						
Rotation-MAI	90-14.8	90-14.8	90-14.8	80-14.9	70-14.1	70-13.3
Average Dia (cm)	46	47	48	48	48	52
Av. Log/Med. Haul	$ 624	1021	1431	2681	3346	3111
Site 28 at 6 m						
Rotation-MAI	90-11.2	100-11.2	80-10.9	90-11.3	90-11.0	80-9.9
Average Dia (cm)	39	42	38	46	48	50
Av. Log/Med. Haul	$ 489	581	818	2463	2962	3254
Site 23 at 6 m						
Rotation-MAI	70-6.5	100-7.8	100-7.8	90-7.3	90-7.0	100-6.8
Average Dia (cm)	28	35	36	40	42	48
Av. Log/Med. Haul	$ 293	423	561	1582	1810	2282
Site 33 at 12 m						
Rotation-MAI	90-14.7	80-14.9	80-14.9	80-14.9	70-14.2	70-13.6
Average Dia (cm)	45	42	44	47	47	51
Av. Log/Med. Haul	$ 335	464	1338	2679	3537	3795
Site 28 at 12 m						
Rotation-MAI	80-10.9	80-10.9	80-10.8	80-10.7	90-10.9	80-9.7
Average Dia (cm)	35	36	38	42	47	48
Av. Log/Med. Haul	$ 151	487	1104	2438	3227	3825
Site 23 at 12 m						
Rotation-MAI	70-6.7	70-6.7	80-7.1	90-7.2	90-6.9	90-6.3
Average Dia (cm)	27	28	33	38	41	44
Av. Log/Med. Haul	$ 371	485	981	1552	2091	2419

Appendix 1 - Discounted Net Revenue (DNR) Tables

SOUTHERN INTERIOR

Maximum dollar amount that can be spent per hectare to treat the regime to the specifications shown and yield a return of 4% real. Treatment at a cost lower than the amount shown will yield more than 4% real. Treatment at a cost higher than the amount shown will yield less than 4% real.

Minimum volume for a merchantable stand:

> **200 m3 per hectare at 12.5 (spruce 17.5) cm d.b.h. utilization.**

Zero entries indicate that a 4% return cannot be attained by treatment at any cost.

Select the characteristics that most closely match the situation for the stand being considered for spacing (species, initial density, site, and height) and then consider the pertinent row showing the estimated outcomes (Rotation--MAI, Average stand diameter and Discounted Net Revenue) for a range of leave densities.

The highest DNR (after subtracting estimated spacing costs) is the best choice and presupposes that the indicated rotation will be used. The consequences of selecting a leave density other than the optimum is the difference between the two DNR's.

The tables can be used to:

1) select an appropriate leave density (including the discounted net revenue foregone if the optimum is not chosen)

2) determine if spacing is feasible (the DNR shown must exceed the anticipated cost of spacing)

3) determine a priority for spacing for the stand (i.e. an index number that can be used for comparative purposes, obtained by dividing the DNR number by the anticipated cost of spacing.

NORTHERN INTERIOR - LODGEPOLE PINE

Regime (Stems untreated)	Treatment (No. of stems after spacing)							
20,000 (repression)	2100	1600	1400	1200	1000	800	600	500
Site 22 at 4 m								
Rotation-MAI	70-5.9	70-6.1	70-6.2	70-6.1	60-5.8	80-5.9	80-5.4	80-5.1
Average Dia (cm)	22	24	25	27	27	33	36	38
Av. Log/Med. Haul	$ 323	489	575	725	824	1154	1566	1674
Site 18 at 4 m								
Rotation-MAI	60-3.6	80-4.1	70-3.9	60-3.6	70-3.7	70-3.5	90-3.4	90-3.1
Average Dia (cm)	18	22	22	22	25	27	33	35
Av. Log/Med. Haul	$ 217	288	357	407	483	549	686	799
Site 14 at 4 m								
Rotation-MAI	90-2.5	90-2.5	100-2.6	90-2.4	90-2.3	100-2.2	110-2.0	110-1.8
Average Dia (cm)	18	20	22	22	24	27	31	33
Av. Log/Med. Haul	$ 89	118	137	166	207	224	253	288
Site 22 at 10 m								
Rotation-MAI	80-4.1	70-4.0	80-4.1	80-4.0	70-3.6	90-3.7	100-3.4	110-3.2
Average Dia (cm)	20	20	22	23	23	28	32	35
Av. Log/Med. Haul	$ 12	102	140	192	257	326	407	481
Site 18 at 10 m								
Rotation-MAI	100-2.7	100-2.6	90-2.5	100-2.5	90-2.3	110-2.3	110-2.0	120-1.9
Average Dia (cm)	18	20	20	22	22	26	28	30
Av. Log/Med. Haul	$ 73	119	167	184	229	226	242	217

Site 14 at 10 m - No significant discounted net revenues

NORTHERN INTERIOR - LODGEPOLE PINE

Regime (Stems untreated)	Treatment (No. of stems after spacing)								
10,000 (repression)	**2100**	**1600**	**1400**	**1200**	**1000**	**800**	**700**	**600**	**50(**
Site 22 at 4 m									
Rotation-MAI	80-5.8	80-5.9	80-6.0	70-6.0	90-5.9	90-5.9	100-5.6	80-5.3	80-4.9
Average Dia (cm)	25	26	27	27	32	34	37	36	38
Av. Log/Med. Haul	$ 353	449	534	703	836	1085	1267	1587	168?
Site 18 at 4 m									
Rotation-MAI	70-3.8	80-4.1	70-3.9	70-3.8	70-3.6	70-3.4	90-3.6	80-3.2	100-3.2
Average Dia (cm)	19	22	22	23	25	27	31	31	3?
Av. Log/Med. Haul	$ 186	268	335	379	464	532	573	629	789
Site 14 at 4 m									
Rotation-MAI	90-2.5	90-2.5	90-2.5	90-2.4	90-2.3	100-2.2	100-2.1	110-2.0	110-1.8
Average Dia (cm)	18	19	20	22	23	26	27	29	31
Av. Log/Med. Haul	$ 90	109	124	177	196	213	225	210	241

10,000 (repression)	**2100**	**1600**	**1400**	**1200**	**1000**	**800**	**600**	**500**
Site 22 at 10 m								
Rotation-MAI	90-4.7	90-4.7	70-4.6	70-4.5	80-4.5	90-4.4	80-3.8	100-3.7
Average Dia (cm)	23	24	22	23	26	29	30	35
Av. Log/Med. Haul	$ 56	125	236	300	383	421	549	695
Site 18 at 10 m								
Rotation-MAI	90-3.1	80-2.9	100-3.1	90-2.9	80-2.6	90-3.2	100-2.3	110-2.1
Average Dia (cm)	18	19	22	22	22	24	28	31
Av. Log/Med. Haul	$ 41	130	126	190	244	334	260	271

Site 14 at 10 m - No significant discounted net revenues

NORTHERN INTERIOR - LODGEPOLE PINE

Regime (Stems untreated)	Treatment (No. of stems after spacing)							
10,000 (repression)	**2100**	**1600**	**1400**	**1200**	**1000**	**800**	**600**	**500**
Site 22 at 17 m								
Rotation-MAI	70-4.5	80-4.5	70-4.2	80-4.2	80-4.0	70-3.9	90-3.3	100-3.1
Average Dia (cm)	20	22	21	23	24	23	28	31
Av. Log/Med. Haul	$ 136	123	140	157	196	322	129	144
Site 18 at 17 m								
Rotation-MAI	90-2.9	80-2.6	90-2.7	90-2.5	90-2.3	100-2.2	130-2.0	120-1.8
Average Dia (cm)	18	18	20	20	21	23	28	28
Av. Log/Med. Haul	$ 124	240	268	227	215	185	184	62

Site 14 at 17 m - No significant discounted net revenues

7,000 (repression)	**2100**	**1600**	**1400**	**1200**	**1000**	**800**	**700**	**600**	**500**
Site 22 at 4 m									
Rotation-MAI	80-5.8	80-5.9	80-5.9	80-6.0	90-5.9	90-5.8	100-5.5	90-5.3	80-4.8
Average Dia (cm)	26	26	27	29	32	34	37	37	38
Av. Log/Med. Haul	$ 285	303	384	567	680	924	1096	1296	1494
Site 18 at 4 m									
Rotation-MAI	70-3.8	80-4.0	80-4.0	70-3.7	80-3.8	80-3.6	70-3.2	80-3.2	90-3.0
Average Dia (cm)	19	22	23	23	26	28	28	31	34
Av. Log/Med. Haul	$ 144	224	268	331	393	462	496	574	631
Site 14 at 4 m									
Rotation-MAI	90-2.4	90-2.5	90-2.4	100-2.4	90-2.3	100-2.2	100-2.1	110-2.0	120-1.8
Average Dia (cm)	18	19	20	22	23	26	27	29	32
Av. Log/Med. Haul	$ 75	94	108	122	179	197	208	192	202

NORTHERN INTERIOR - LODGEPOLE PINE

Regime (Stems untreated)	Treatment (No. of stems after spacing)							
7,000	2100	1600	1400	1200	1000	800	600	500
Site 22 at 10 m								
Rotation-MAI	80-5.2	80-5.2	70-5.1	70-5.1	80-5.1	90-4.9	90-4.4	100-4.2
Average Dia (cm)	23	24	23	24	27	30	33	36
Av. Log/Med. Haul	$ 21	101	168	241	321	365	599	769
Site 18 at 10 m								
Rotation-MAI	80-3.4	70-3.1	70-3.0	70-3.0	80-3.0	80-2.8	90-2.6	100-2.4
Average Dia (cm)	18	18	19	20	23	24	28	31
Av. Log/Med. Haul	$ 61	112	160	205	276	288	336	354
Site 14 at 10 m - No significant discounted net revenues								
Site 22 at 17 m								
Rotation-MAI	80-5.1	70-5.0	70-4.8	80-4.8	80-4.6	80-4.2	80-3.7	90-3.5
Average Dia (cm)	23	22	22	24	25	26	28	31
Av. Log/Med. Haul	$ 23	147	92	51	120	113	122	177
Site 18 at 17 m								
Rotation-MAI	80-3.2	70-2.9	80-3.0	80-2.8	80-2.6	90-2.5	100-2.2	110-2.0
Average Dia (cm)	18	18	20	20	21	23	26	28
Av. Log/Med. Haul	$ 140	258	316	245	256	208	146	57
Site 14 at 17 m - No significant discounted net revenues								

NORTHERN INTERIOR - LODGEPOLE PINE

Regime (Stems untreated)	Treatment (No. of stems after spacing)							
5,000	2100	1600	1400	1200	1000	800	700	600	500
Site 22 at 4 m									
Rotation-MAI	80-5.8	80-5.9	80-5.9	70-5.8	90-5.8	90-5.7	100-5.4	90-5.2	80-4.7
Average Dia (cm)	26	27	28	27	32	34	37	37	37
Av. Log/Med. Haul	$ 167	259	341	412	554	792	961	1156	1225
Site 18 at 4 m									
Rotation-MAI	90-4.0	80-4.0	80-3.9	70-3.7	80-3.7	80-3.5	80-3.3	90-3.2	90-3.0
Average Dia (cm)	22	22	23	23	26	28	29	32	34
Av. Log/Med. Haul	$ 65	138	181	243	305	375	398	457	534
Site 14 at 4 m									
Rotation-MAI	90-2.4	90-2.5	90-2.4	100-2.4	90-2.2	100-2.2	100-2.0	110-1.9	120-1.8
Average Dia (cm)	18	19	20	22	23	26	27	29	32
Av. Log/Med. Haul	$ 50	68	82	96	152	170	180	164	172

5,000	2100	1600	1400	1200	1000	800	600	500
Site 22 at 10 m								
Rotation-MAI	80-5.7	70-6.0	60-5.8	70-6.0	60-5.5	90-5.6	90-5.2	90-5.0
Average Dia (cm)	25	23	22	25	25	32	35	37
Av. Log/Med. Haul	$ 95	128	181	311	417	588	962	1208
Site 18 at 10 m								
Rotation-MAI	70-3.8	90-4.0	90-4.0	90-3.9	70-3.4	80-3.4	90-3.1	100-3.0
Average Dia (cm)	18	22	23	24	23	26	30	33
Av. Log/Med. Haul	$ 43	92	145	188	301	353	418	469
Site 14 at 10 m								
Rotation-MAI	100-2.5	90-2.3	90-2.2	110-2.3	100-2.2	100-2.0	110-1.8	120-1.7
Average Dia (cm)	18	18	19	22	22	24	27	30
Av. Log/Med. Haul	$ 56	94	122	111	156	202	196	196

NORTHERN INTERIOR - LODGEPOLE PINE

Regime (Stems untreated)	Treatment (No. of stems after spacing)							
5,000	2100	1600	1400	1200	1000	800	600	500
Site 22 at 17 m								
Rotation-MAI	70-5.8	70-5.7	70-5.6	70-5.4	70-5.1	70-4.7	100-4.6	110-4.1
Average Dia (cm)	22	23	23	24	25	26	33	36
Av. Log/Med. Haul	$ 60	173	141	222	259	251	295	415
Site 18 at 17 m								
Rotation-MAI	80-3.8	70-3.4	80-3.5	70-3.1	70-2.9	90-3.0	90-2.6	100-2.4
Average Dia (cm)	20	19	21	20	21	25	26	29
Av. Log/Med. Haul	$ 111	147	121	181	179	153	83	60
Site 14 at 17 m								
Rotation-MAI	100-2.4	100-2.2	100-2.1	110-2.1	110-1.9	120-1.8	130-1.6	150-1.4
Average Dia (cm)	18	19	19	21	21	23	26	27
Av. Log/Med. Haul	$ 214	279	245	171	123	91	63	0

3,000	800	600	500	400
Site 22 at 4 m				
Rotation-MAI	80-5.7	80-5.0	80-4.5	80-3.9
Average Dia (cm)	32	35	37	39
Av. Log/Med. Haul	$ 560	866	1013	898
Site 18 at 4 m				
Rotation-MAI	70-3.2	90-3.2	100-2.9	90-2.4
Average Dia (cm)	26	32	35	35
Av. Log/Med. Haul	$ 269	382	443	434
Site 14 at 4 m				
Rotation-MAI	100-2.1	110-1.9	120-1.7	140-1.5
Average Dia (cm)	25	29	31	34
Av. Log/Med. Haul	$ 116	134	117	79

NORTHERN INTERIOR - LODGEPOLE PINE

Regime (Stems untreated)	Treatment (No. of stems after spacing)			
1,600 (Planted)	800	600	500	400
Site 22 at 4 m				
Rotation-MAI	70-5.7	80-5.4	80-5.0	70-4.3
Average Dia (cm)	31	36	38	39
Av. Log/Med. Haul	$ 564	1052	1149	1121
Site 18 at 4 m				
Rotation-MAI	70-3.5	80-3.3	100-3.2	90-2.8
Average Dia (cm)	27	31	36	37
Av. Log/Med. Haul	$ 257	347	485	560
Site 14 at 4 m				
Rotation-MAI	100-2.2	110-2.0	110-1.8	130-1.6
Average Dia (cm)	26	29	31	35
Av. Log/Med. Haul	$ 91	90	118	113

NORTHERN INTERIOR - WHITE SPRUCE

Regime (Stems untreated)	Treatment (No. of stems after spacing)							
10,000	1600	1400	1200	1000	800	700	600	500
Site 21 at 4 m								
Rotation-MAI	90-5.7	90-5.8	90-5.9	90-5.9	100-6.0	100-5.9	100-5.7	90-5.2
Average Dia (cm)	26	27	28	30	34	35	37	38
Av. Log/Med. Haul	$ 278	387	499	713	980	1113	1381	1689
Site 17 at 4 m								
Rotation-MAI	100-4.2	100-4.2	100-4.3	90-3.9	100-4.2	110-4.3	100-3.9	100-3.7
Average Dia (cm)	24	25	26	26	30	33	33	35
Av. Log/Med. Haul	$ 241	312	387	497	653	718	846	1001
Site 13 at 4 m								
Rotation-MAI	100-2.3	110-2.7	100-2.5	100-2.5	110-2.7	110-2.6	100-2.2	120-2.5
Average Dia (cm)	20	22	22	23	27	28	28	33
Av. Log/Med. Haul	$ 131	168	225	261	352	376	418	477

7,000	1600	1400	1200	1000	800	700	600	500
Site 21 at 4 m								
Rotation-MAI	90-5.6	90-5.7	90-5.8	90-5.8	90-5.7	100-5.7	100-5.6	90-5.1
Average Dia (cm)	26	27	28	29	32	35	37	37
Av. Log/Med. Haul	$ 254	359	472	571	873	1055	1312	1462
Site 17 at 4 m								
Rotation-MAI	90-3.7	90-3.8	100-4.2	100-4.2	90-3.7	100-3.9	110-4.0	110-3.8
Average Dia (cm)	22	23	26	27	28	31	34	36
Av. Log/Med. Haul	$ 206	266	366	429	588	662	749	906
Site 13 at 4 m								
Rotation-MAI	120-2.8	110-2.5	100-2.3	100-2.4	100-2.3	100-2.2	110-2.3	130-2.6
Average Dia (cm)	22	22	22	23	25	26	29	34
Av. Log/Med. Haul	$ 108	154	208	242	310	335	373	433

NORTHERN INTERIOR - WHITE SPRUCE

Regime (Stems untreated)	Treatment (No. of stems after spacing)							
5,000	1600	1400	1200	1000	800	700	600	500
Site 21 at 4 m								
Rotation-MAI	90-5.6	90-5.6	90-5.7	90-5.7	110-5.8	100-5.6	90-5.2	100-5.2
Average Dia (cm)	26	27	28	29	35	35	35	39
Av. Log/Med. Haul	$ 237	341	453	549	755	1017	1202	1478
Site 17 at 4 m								
Rotation-MAI	90-3.6	90-3.7	100-4.1	100-4.1	100-4.0	90-3.5	110-3.9	110-3.7
Average Dia (cm)	22	23	26	27	29	29	34	36
Av. Log/Med. Haul	$ 152	213	313	374	488	561	682	837
Site 13 at 4 m								
Rotation-MAI	120-2.7	120-2.8	110-2.5	100-2.3	100-2.2	100-2.1	110-2.3	140-2.6
Average Dia (cm)	22	23	23	23	25	26	29	35
Av. Log/Med. Haul	$ 90	120	169	227	283	307	344	376

1,600 (planted)	800	700	600	500
Site 21 at 4 m				
Rotation-MAI	80-5.5	100-5.8	100-5.6	90-5.2
Average Dia (cm)	30	35	37	37
Av. Log/Med. Haul	$ 637	786	1037	1215
Site 17 at 4 m				
Rotation-MAI	90-3.9	100-4.1	90-3.7	100-3.7
Average Dia (cm)	28	31	31	35
Av. Log/Med. Haul	$ 370	424	518	712
Site 13 at 4 m				
Rotation-MAI	100-2.4	100-2.3	120-2.7	130-2.7
Average Dia (cm)	25	26	31	34
Av. Log/Long Haul	$ 194	221	273	312

Appendix 1 - Discounted Net Revenue (DNR) Tables

COAST

Maximum dollar amount that can be spent per hectare to treat the regime to the specifications shown and yield a return of 4% real. Treatment at a cost lower than the amount shown will yield more than 4% real. Treatment at a cost higher than the amount shown will yield less than 4% real.

Minimum volume for a merchantable stand:

300 m3 per hectare at 17.5 cm d.b.h. utilization.

Zero entries indicate that a 4% return cannot be attained by treatment at any cost.

Select the characteristics that most closely match the situation for the stand being considered for spacing (species, initial density, site, and height) and then consider the pertinent row showing the estimated outcomes (Rotation--MAI, Average stand diameter and Discounted Net Revenue) for a range of leave densities.

The highest DNR (after subtracting estimated spacing costs) is the best choice and presupposes that the indicated rotation will be used. The consequences of selecting a leave density other than the optimum is the difference between the two DNR's.

The tables can be used to:

1) select an appropriate leave density (including the discounted net revenue foregone if the optimum is not chosen)

2) determine if spacing is feasible (the DNR shown must exceed the anticipated cost of spacing)

3) determine a priority for spacing for the stand (i.e. an index number that can be used for comparative purposes, obtained by dividing the DNR number by the anticipated cost of spacing.

NORTHERN INTERIOR - HEMLOCK

Regime (Stems untreated)	Treatment (No. of stems after spacing)							
10,000	**1600**	**1400**	**1200**	**1000**	**816**	**700**	**600**	**500**
Site 20 at 6 m								
Rotation-MAI	90-6.3	90-6.2	90-6.1	90-5.9	110-6.3	100-5.9	100-5.7	90-5.0
Average Dia (cm)	26	27	29	30	35	36	38	38
Av. Log/Med. Haul	$ 273	346	515	589	777	1125	1329	1400
Site 16 at 6 m								
Rotation-MAI	70-3.6	80-3.7	70-3.3	90-3.6	90-3.5	100-3.6	110-3.6	110-3.4
Average Dia (cm)	20	22	22	26	28	31	34	36
Av. Log/Med. Haul	$ 228	282	339	387	483	534	603	726
Site 12 at 6 m								
Rotation-MAI	90-2.3	100-2.3	110-2.3	100-2.1	110-2.1	110-2.0	110-1.8	120-1.8
Average Dia (cm)	19	20	22	22	25	26	27	29
Av. Log/Med. Haul	$ 155	130	147	179	206	224	232	213

7,000	**1600**	**1400**	**1200**	**1000**	**816**	**700**	**600**	**500**
Site 20 at 6 m								
Rotation-MAI	90-6.2	90-6.1	80-5.7	90-5.9	110-6.2	100-5.8	100-5.6	90-4.9
Average Dia (cm)	26	27	27	30	35	36	38	38
Av. Log/Med. Haul	$ 208	473	420	523	715	1041	1246	1326
Site 16 at 6 m								
Rotation-MAI	70-3.6	80-3.7	80-3.5	90-3.6	80-3.2	100-3.6	110-3.6	120-3.4
Average Dia (cm)	20	22	23	26	26	31	34	37
Av. Log/Med. Haul	$ 203	258	296	365	433	513	582	626
Site 12 at 6 m								
Rotation-MAI	100-2.3	100-2.2	110-2.2	100-2.0	110-2.0	110-2.0	120-1.9	120-1.8
Average Dia (cm)	19	20	22	22	25	26	28	29
Av. Log/Med. Haul	$ 110	120	138	169	197	217	204	205

NORTHERN INTERIOR - HEMLOCK

Regime (Stems untreated)	Treatment (No. of stems after spacing)							
5,000	1600	1400	1200	1000	816	700	600	500
Site 20 at 6 m								
Rotation-MAI	90-6.2	90-6.1	90-5.9	90-5.8	110-6.2	110-6.0	100-5.6	90-4.9
Average Dia (cm)	26	27	28	30	35	38	38	38
Av. Log/Med. Haul	$ 214	288	360	531	724	1084	1261	1341
Site 16 at 6 m								
Rotation-MAI	70-3.5	80-3.6	80-3.5	90-3.6	80-3.2	100-3.6	110-3.6	110-3.4
Average Dia (cm)	20	22	23	26	26	31	34	36
Av. Log/Med. Haul	$ 200	257	296	367	433	526	601	712
Site 12 at 6 m								
Rotation-MAI	100-2.3	100-2.2	110-2.2	110-2.1	110-2.0	110-1.9	110-1.8	140-1.9
Average Dia (cm)	19	20	22	23	25	26	27	31
Av. Log/Med. Haul	$ 99	110	127	145	186	202	216	225

SOUTHERN INTERIOR - LODGEPOLE PINE

Regime (Stems untreated)	Treatment (No. of stems after spacing)							
20,000 (repression)	2100	1600	1400	1200	1000	800	600	500
Site 22 at 4 m								
Rotation-MAI	70-5.9	70-6.1	70-6.2	70-6.1	60-5.8	80-5.9	80-5.4	80-5.1
Average Dia (cm)	22	24	25	27	27	33	36	38
Av. Log/Med. Haul	$ 341	509	595	746	852	1116	1422	1530
Site 18 at 4 m								
Rotation-MAI	60-3.6	80-4.1	70-3.9	60-3.6	70-3.7	70-3.5	90-3.4	90-3.1
Average Dia (cm)	18	22	22	22	25	27	33	35
Av. Log/Med. Haul	$ 220	300	375	432	501	567	668	756
Site 14 at 4 m								
Rotation-MAI	90-2.5	90-2.5	100-2.6	90-2.4	90-2.3	100-2.2	110-2.0	110-1.8
Average Dia (cm)	18	20	22	22	24	27	31	33
Av. Log/Med. Haul	$ 0	0	145	177	218	232	253	283
Site 22 at 10 m								
Rotation-MAI	80-4.1	70-4.0	80-4.1	80-4.0	70-3.6	90-3.7	90-3.3	90-3.1
Average Dia (cm)	20	20	22	23	23	28	30	32
Av. Log/Med. Haul	$ 11	103	168	219	292	348	389	460
Site 18 at 10 m								
Rotation-MAI	90-2.6	90-2.5	90-2.5	100-2.5	90-2.3	110-2.3	110-2.0	120-1.9
Average Dia (cm)	17	19	20	22	22	26	28	30
Av. Log/Med. Haul	$ 73	134	159	187	237	226	241	210

Site 14 at 10 m - No significant discounted net revenues

SOUTHERN INTERIOR - LODGEPOLE PINE

Regime (Stems untreated)	Treatment (No. of stems after spacing)								
10,000 (repression)	2100	1600	1400	1200	1000	800	700	600	
Site 22 at 4 m									
Rotation-MAI	70-5.8	70-6.0	70-6.0	70-6.0	80-6.0	90-5.9	80-5.6	80-5.3	80-
Average Dia (cm)	23	24	25	27	30	34	34	36	3
Av. Log/Med. Haul	$ 365	466	549	723	815	1046	1202	1426	15
Site 18 at 4 m									
Rotation-MAI	70-3.8	80-4.1	70-3.9	60-3.5	70-3.6	70-3.4	70-3.2	80-3.2	100-
Average Dia (cm)	19	22	22	22	25	27	28	31	
Av. Log/Med. Haul	$ 182	280	352	411	482	549	566	621	72
Site 14 at 4 m									
Rotation-MAI	90-2.5	90-2.5	90-2.5	90-2.4	90-2.3	100-2.2	100-2.1	110-2.0	110-1.
Average Dia (cm)	18	19	20	22	23	26	27	29	
Av. Log/Med. Haul	$ 0	0	126	190	208	223	235	217	

10,000 (repression)	2100	1600	1400	1200	1000	800	600	500
Site 22 at 10 m								
Rotation-MAI	90-4.7	80-4.7	80-4.7	80-4.7	80-4.5	90-4.4	80-3.8	100-3.7
Average Dia (cm)	23	22	23	24	26	29	30	35
Av. Log/Med. Haul	$ 73	144	214	280	408	435	562	637
Site 18 at 10 m								
Rotation-MAI	80-2.9	80-2.9	100-3.1	90-2.9	80-2.6	90-3.2	100-2.3	100-2.1
Average Dia (cm)	17	19	22	22	22	24	28	29
Av. Log/Med. Haul	$ 44	126	133	203	263	349	266	265

Site 14 at 10 m - No significant discounted net revenues

SOUTHERN INTERIOR - LODGEPOLE PINE

Regime (Stems untreated)	Treatment (No. of stems after spacing)							
10,000 (repression)	2100	1600	1400	1200	1000	800	600	500
Site 22 at 17 m								
Rotation-MAI	70-4.5	90-4.5	70-4.2	80-4.2	80-4.0	70-3.9	90-3.3	90-3.0
Average Dia (cm)	20	23	21	23	24	23	28	29
Av. Log/Med. Haul	$ 3	41	173	209	246	390	162	137
Site 18 at 17 m								
Rotation-MAI	80-2.7	80-2.6	90-2.7	90-2.5	90-2.3	100-2.2	110-2.0	120-1.8
Average Dia (cm)	17	18	20	20	21	23	26	28
Av. Log/Med. Haul	$ 121	225	237	197	211	188	126	44

Site 14 at 17 m - No significant discounted net revenues

7,000	2100	1600	1400	1200	1000	800	700	600	500
Site 22 at 4 m									
Rotation-MAI	70-5.8	80-5.9	80-5.9	80-6.0	80-5.9	90-5.8	80-5.5	90-5.3	80-4.8
Average Dia (cm)	24	26	27	29	30	34	34	37	38
Av. Log/Med. Haul	$ 288	306	388	567	647	877	1030	1146	1330
Site 18 at 4 m									
Rotation-MAI	90-4.0	80-4.0	80-4.0	70-3.7	80-3.8	80-3.6	80-3.4	80-3.2	90-3.0
Average Dia (cm)	22	22	23	23	26	28	29	31	34
Av. Log/Med. Haul	$ 156	235	279	348	405	460	496	565	612
Site 14 at 4 m									
Rotation-MAI	90-2.4	90-2.5	90-2.4	100-2.4	90-2.3	100-2.2	100-2.1	110-2.0	110-1.8
Average Dia (cm)	18	19	20	22	23	26	27	29	32
Av. Log/Med. Haul	$ 0	0	102	124	183	199	209	190	190

SOUTHERN INTERIOR - LODGEPOLE PINE

Regime (Stems untreated)	Treatment (No. of stems after spacing)							
7,000	**2100**	**1600**	**1400**	**1200**	**1000**	**800**	**600**	**500**
Site 22 at 10 m								
Rotation-MAI	80-5.2	80-5.2	70-5.1	70-5.1	80-5.1	80-4.8	90-4.4	100-4.2
Average Dia (cm)	23	24	23	24	27	28	33	36
Av. Log/Med. Haul	$ 22	102	178	251	323	356	545	653
Site 18 at 10 m								
Rotation-MAI	70-3.2	70-3.1	70-3.0	70-3.0	80-3.0	80-2.8	90-2.6	100-2.4
Average Dia (cm)	17	18	19	20	23	24	28	31
Av. Log/Med. Haul	$ 58	110	156	199	291	302	343	342

Site 14 at 10 m - No significant discounted net revenues

Site 22 at 17 m								
Rotation-MAI	80-5.1	70-5.0	70-4.8	70-4.6	80-4.6	80-4.2	90-3.8	90-3.5
Average Dia (cm)	23	22	22	22	22	26	29	31
Av. Log/Med. Haul	$ 24	166	109	55	117	107	28	114
Site 18 at 17 m								
Rotation-MAI	70-3.0	70-2.9	80-3.0	80-2.8	90-2.8	90-2.5	100-2.2	110-2.0
Average Dia (cm)	17	18	20	20	22	23	26	28
Av. Log/Med. Haul	$ 128	251	290	221	274	222	145	46

Site 14 at 10 m - No significant discounted net revenues

SOUTHERN INTERIOR - LODGEPOLE PINE

Regime (Stems untreated)	Treatment (No. of stems after spacing)							
5,000	2100	1600	1400	1200	1000	800	700	600	500
Site 22 at 4 m									
Rotation-MAI	80-5.8	70-5.9	80-5.9	80-5.9	80-5.8	90-5.7	90-5.5	90-5.2	80-4.7
Average Dia (cm)	26	25	28	29	30	34	35	37	37
Av. Log/Med. Haul	$ 169	262	344	437	519	745	829	1006	1067
Site 18 at 4 m									
Rotation-MAI	90-4.0	80-4.0	80-3.9	70-3.7	80-3.7	80-3.5	80-3.3	90-3.2	90-3.0
Average Dia (cm)	22	22	23	23	26	28	29	32	34
Av. Log/Med. Haul	$ 71	150	193	260	317	388	407	436	516
Site 14 at 4 m									
Rotation-MAI	90-2.4	90-2.3	90-2.4	100-2.4	90-2.2	100-2.2	100-2.0	110-1.9	120-1.8
Average Dia (cm)	18	19	20	22	23	26	27	29	32
Av. Log/Med. Haul	$ 0	0	70	91	149	165	175	155	154

5,000	2100	1600	1400	1200	1000	800	600	500
Site 22 at 10 m								
Rotation-MAI	80-5.7	70-6.0	60-5.8	70-6.0	60-5.5	60-5.3	90-5.2	90-5.0
Average Dia (cm)	25	23	22	25	25	27	35	37
Av. Log/Med. Haul	$ 96	139	203	322	438	563	852	1040
Site 18 at 10 m								
Rotation-MAI	70-3.8	60-3.4	90-4.0	90-3.9	70-3.5	80-3.4	90-3.1	80-2.7
Average Dia (cm)	18	18	23	24	21	26	30	30
Av. Log/Med. Haul	$ 47	100	165	208	336	378	430	466
Site 14 at 10 m								
Rotation-MAI	90-2.4	90-2.3	90-2.2	100-2.3	100-2.2	100-2.0	110-1.8	120-1.7
Average Dia (cm)	17	18	19	21	22	24	27	30
Av. Log/Med. Haul	$ 42	72	99	96	145	190	180	175

SOUTHERN INTERIOR - LODGEPOLE PINE

Regime (Stems untreated)	Treatment (No. of stems after spacing)							
5,000	2100	1600	1400	1200	1000	800	600	500
Site 22 at 17 m								
Rotation-MAI	70-5.8	70-5.7	70-5.6	70-5.4	60-4.8	70-4.7	100-4.6	80-3.9
Average Dia (cm)	22	23	23	24	23	26	33	31
Av. Log/Med. Haul	$ 62	175	141	221	205	243	187	246
Site 18 at 17 m								
Rotation-MAI	90-3.8	70-3.4	80-3.5	70-3.1	70-2.9	80-2.8	90-2.6	90-2.3
Average Dia (cm)	22	19	21	20	21	23	26	27
Av. Log/Med. Haul	$ 154	155	149	188	221	197	118	89
Site 14 at 17 m								
Rotation-MAI	90-2.3	100-2.2	100-2.1	110-2.1	110-1.9	120-1.8	130-1.6	150-1.4
Average Dia (cm)	17	19	19	21	21	23	26	27
Av. Log/Med. Haul	$ 146	169	136	75	26	0	0	0

3,000	800	600	500	400
Site 22 at 4 m				
Rotation-MAI	80-5.7	80-5.0	80-4.5	80-3.9
Average Dia (cm)	32	35	37	39
Av. Log/Med. Haul	$ 503	762	857	756
Site 18 at 4 m				
Rotation-MAI	70-3.2	90-3.2	100-2.9	90-2.4
Average Dia (cm)	26	32	35	35
Av. Log/Med. Haul	$ 298	374	417	409
Site 14 at 4 m				
Rotation-MAI	100-2.1	110-1.9	120-1.7	140-1.5
Average Dia (cm)	25	29	31	34
Av. Log/Med. Haul	$ 117	132	110	70

SOUTHERN INTERIOR - LODGEPOLE PINE

Regime (Stems untreated)	Treatment (No. of stems after spacing)			
1,600 (Planted)	800	600	500	400
Site 22 at 4 m				
Rotation-MAI	70-5.7	80-5.4	80-5.0	70-4.3
Average Dia (cm)	31	36	38	39
Av. Log/Med. Haul	$ 530	896	993	966
Site 18 at 4 m				
Rotation-MAI	70-3.5	80-3.3	100-3.2	90-2.8
Average Dia (cm)	27	31	32	37
Av. Log/Med. Haul	$ 267	335	422	493
Site 14 at 4 m				
Rotation-MAI	100-2.2	110-2.0	110-1.8	130-1.6
Average Dia (cm)	26	29	31	35
Av. Log/Med. Haul	$ 97	94	117	103

SOUTHERN INTERIOR - WHITE SPRUCE & ENGELMANN SPRUCE

Regime (Stems untreated)	Treatment (No. of stems after spacing)							
10,000	**1600**	**1400**	**1200**	**1000**	**800**	**700**	**600**	**500**
Site 21 at 4 m								
Rotation-MAI	90-5.7	90-5.8	80-5.6	90-5.9	100-6.0	110-5.9	100-5.7	90-5.2
Average Dia (cm)	26	27	26	30	34	37	37	38
Av. Log/Med. Haul	$ 245	334	433	632	957	1145	1421	1735
Site 17 at 4 m								
Rotation-MAI	100-4.2	100-4.2	100-4.3	90-3.9	100-4.2	110-4.3	120-4.2	100-3.7
Average Dia (cm)	24	25	26	26	30	33	36	35
Av. Log/Med. Haul	$ 224	283	346	442	584	675	828	980
Site 13 at 4 m								
Rotation-MAI	120-2.8	110-2.7	100-2.5	100-2.5	110-2.7	110-2.6	120-2.7	120-2.5
Average Dia (cm)	22	22	22	23	27	28	31	33
Av. Log/Med. Haul	$ 118	164	215	250	326	345	387	459

7,000	**1600**	**1400**	**1200**	**1000**	**800**	**700**	**600**	**500**
Site 21 at 4 m								
Rotation-MAI	90-5.6	90-5.7	80-5.5	90-5.8	90-5.7	100-5.7	100-5.6	90-5.1
Average Dia (cm)	26	27	26	29	32	35	37	37
Av. Log/Med. Haul	$ 223	309	404	498	791	1060	1353	1497
Site 17 at 4 m								
Rotation-MAI	90-3.7	90-3.8	100-4.2	100-4.2	90-3.7	100-3.9	110-4.0	120-3.9
Average Dia (cm)	22	23	26	27	28	31	34	38
Av. Log/Med. Haul	$ 179	237	322	374	508	593	717	915
Site 13 at 4 m								
Rotation-MAI	120-2.8	110-2.5	100-2.3	100-2.4	100-2.3	100-2.2	110-2.3	130-2.6
Average Dia (cm)	22	22	22	23	25	26	29	34
Av. Log/Med. Haul	$ 105	147	196	229	289	309	341	424

SOUTHERN INTERIOR - WHITE SPRUCE & ENGELMANN SPRUCE

Regime (Stems untreated)	Treatment (No. of stems after spacing)							
5,000	1600	1400	1200	1000	800	700	600	500
Site 21 at 4 m								
Rotation-MAI	90-5.6	90-5.6	90-5.7	90-5.7	110-5.8	100-5.6	90-5.2	100-5.2
Average Dia (cm)	26	27	28	29	35	35	35	39
Av. Log/Med. Haul	$ 207	293	385	478	775	1023	1196	1543
Site 17 at 4 m								
Rotation-MAI	90-3.6	90-3.7	100-4.1	100-4.1	100-4.0	90-3.5	110-3.9	110-3.7
Average Dia (cm)	22	23	26	27	29	29	34	36
Av. Log/Med. Haul	$ 134	192	278	327	430	492	659	845
Site 13 at 4 m								
Rotation-MAI	120-2.7	120-2.8	110-2.5	100-2.3	100-2.2	100-2.1	110-2.3	140-2.6
Average Dia (cm)	22	23	23	23	25	26	29	35
Av. Log/Med. Haul	$ 81	110	154	199	257	276	307	371

1,600 (Planted)	800	700	600	500
Site 21 at 4 m				
Rotation-MAI	90-5.7	100-5.8	100-5.6	90-5.2
Average Dia (cm)	32	35	37	37
Av. Log/Med. Haul	$ 572	812	1095	1267
Site 17 at 4 m				
Rotation-MAI	90-3.9	100-4.1	110-4.1	100-3.7
Average Dia (cm)	28	31	34	35
Av. Log/Med. Haul	$ 320	386	492	714
Site 13 at 4 m				
Rotation-MAI	100-2.4	100-2.3	120-2.7	130-2.7
Average Dia (cm)	25	26	31	34
Av. Lgo/Med. Haul	$ 193	215	265	321

SOUTHERN INTERIOR - DOUGLAS FIR

Regime (Stems untreated)	Treatment (No. of stems after spacing)						
10,000	**1600**	**1400**	**1200**	**1000**	**800**	**600**	**500**
Site 25 at 4 m							
Rotation-MAI	70-6.3	70-6.3	70-6.4	70-6.3	90-6.6	80-6.2	80-5.9
Average Dia (cm)	24	25	26	28	35	37	40
Av. Log/Med. Haul	$ 484	610	752	999	1552	2328	2510
Site 21 at 4 m							
Rotation-MAI	80-4.6	80-4.6	80-4.6	80-4.6	80-4.4	100-4.5	90-4.1
Average Dia (cm)	22	23	25	27	29	36	36
Av. Log/Med. Haul	$ 367	440	605	775	920	1296	1466
Site 16 at 4 m							
Rotation-MAI	80-2.6	80-2.6	80-2.5	90-2.6	90-2.4	100-2.3	100-2.2
Average Dia (cm)	18	19	20	23	24	28	30
Av. Log/Med. Haul	$ 259	285	300	332	343	373	422

7,000	**1600**	**1400**	**1200**	**1000**	**800**	**600**	**500**
Site 25 at 4 m							
Rotation-MAI	70-6.2	70-6.2	70-6.1	70-6.0	100-6.4	90-6.1	80-5.7
Average Dia (cm)	24	25	26	28	36	38	39
Av. Log/Med. Haul	$ 384	522	636	855	1196	1931	2260
Site 21 at 4 m							
Rotation-MAI	80-4.5	80-4.5	70-4.1	80-4.3	80-4.2	100-4.3	100-4.1
Average Dia (cm)	22	23	22	26	28	35	38
Av. Log/Med. Haul	$ 254	329	396	537	673	972	1286
Site 16 at 4 m							
Rotation-MAI	80-2.6	80-2.5	90-2.6	90-2.5	90-2.4	100-2.3	100-2.1
Average Dia (cm)	18	19	21	22	24	28	30
Av. Log/Med. Haul	$ 270	291	240	295	353	381	424

SOUTHERN INTERIOR - DOUGLAS FIR

Regime (Stems untreated)	Treatment (No. of stems after spacing)						
5,000	1600	1400	1200	1000	800	600	500
Site 25 at 4 m							
Rotation-MAI	70-6.3	70-6.2	70-6.2	70-6.1	90-6.5	80-6.0	80-5.7
Average Dia (cm)	24	25	26	28	35	36	39
Av. Log/Med. Haul	$ 285	405	529	750	1320	1834	2159
Site 21 at 4 m							
Rotation-MAI	70-4.3	80-4.6	80-4.6	80-4.4	80-4.3	90-4.2	100-4.1
Average Dia (cm)	21	23	25	26	28	34	38
Av. Log/Med. Haul	$ 238	294	457	512	656	1043	1240
Site 16 at 4 m							
Rotation-MAI	80-2.6	80-2.6	80-2.5	90-2.5	90-2.4	100-2.3	100-2.2
Average Dia (cm)	18	19	20	22	24	28	30
Av. Log/Med. Haul	$ 224	247	269	250	312	335	386

APPENDIX II

STATISTICS FOR UNTREATED STANDS

Appendix 2 - Statistics for untreated stands

COAST REGION - DOUGLAS FIR

Regime	4,444 (natural)	2,500 (planted)	1,200 (planted)
Site 35 at 6 m			
Rotation-MAI	100-10.8	100-10.9	100-10.7
Average Dia (cm)	50	49	50
Av. Log/Med. Haul	5069	5039	4982
Site 30 at 6 m			
Rotation-MAI	90-8.2	90-8.3	80-8.2
Average Dia (cm)	34	33	33
Av. Log/Med. Haul	1461	1275	1646
Site 25 at 6 m			
Rotation-MAI	90-5.5	90-5.6	70-5.4
Average Dia (cm)	26	26	27
Av. Log/Med. Haul	246	254	633
Site 35 at 12 m			
Rotation-MAI	100-10.8	100-10.9	100-10.7
Average Dia (cm)	50	49	50
Av. Log/Med. Haul	6345	6132	6236
Site 30 at 12 m			
Rotation-MAI	90-8.2	90-8.3	80-8.2
Average Dia (cm)	34	33	33
Av. Log/Med. Haul	1996	1762	2345
Site 25 at 12 m			
Rotation-MAI	90-5.5	90-5.6	70-5.4
Average Dia (cm)	26	26	27
Av. Log/Med. Haul	452	465	1075

COAST REGION - HEMLOCK

Regime	10,000 (natural)	7,000 (natural)	5,000 (natural)	3,000 (natural)
Site 33 at 6 m				
Rotation-MAI	90-15.6	90-15.3	90-15.2	90-15.1
Average Dia (cm)	42	43	43	44
Av. Log/Med. Haul	5130	5404	5351	5674
Site 28 at 6 m				
Rotation-MAI	110-11.9	120-11.5	110-11.5	110-11.4
Average Dia (cm)	40	43	41	42
Av. Log/Med. Haul	2252	2236	2384	2580
Site 23 at 6 m				
Rotation-MAI	80-8.1	80-7.8	80-7.6	70-6.9
Average Dia (cm)	24	25	25	24
Av. Log/Med. Haul	678	730	711	778
Site 33 at 12 m				
Rotation-MAI	90-15.6	90-15.3	90-15.2	90-15.1
Average Dia (cm)	42	43	43	44
Av. Log/Med. Haul	6375	6685	6621	6889
Site 28 at 12 m				
Rotation-MAI	110-11.9	110-11.6	110-11.5	110-11.4
Average Dia (cm)	40	40	41	42
Av. Log/Med. Haul	3053	2993	3210	3451
Site 23 at 12 m				
Rotation-MAI	80-8.1	80-7.8	80-7.6	70-6.9
Average Dia (cm)	24	25	25	24
Av. Log/Med. Haul	1144	1223	1194	1297

NORTHERN INTERIOR REGION - HEMLOCK

Regime	10,000 (natural)	7,000 (natural)	5,000 (natural)
Site 20 at 6 m			
Rotation-MAI	110-7.0	110-6.8	110-6.8
Average Dia (cm)	26	27	27
Av. Log/Med. Haul	570	622	607
Site 16 at 6 m			
Rotation-MAI	130-4.8	120-4.6	120-4.5
Average Dia (cm)	23	22	22
Av. Log/Med. Haul	131	146	141
Site 12 at 6 m			
Rotation-MAI	150-2.8	150-2.7	140-2.7
Average Dia (cm)	16	17	17
Av. Log/Med. Haul	-38	-32	-24

NORTHERN INTERIOR REGION - WHITE SPRUCE

Regime	10,000 (natural)	7,000 (natural)	5,000 (natural)	1,600 (planted)
Site 21 at 4m				
Rotation-MAI	100-5.2	100-5.3	100-5.3	70-5.0
Average Dia (cm)	26	26	26	22
Av. Log/Med. Haul	669	680	687	763
Site 17 at 4 m				
Rotation-MAI	110-3.7	110-3.8	110-3.8	90-3.8
Average Dia (cm)	22	22	23	22
Av. Log/Med. Haul	238	245	288	395
Site 13 at 4 m				
Rotation-MAI	120-2.2	120-2.2	140-2.7	100-2.3
Average Dia (cm)	18	18	22	19
Av. Log/Med. Haul	42	46	60	120

NORTHERN INTERIOR REGION - LODGEPOLE PINE

Regime	20,000 (repression)	10,000 (repression)	7,000 (repression)	5,000 (natural)	3,000 (natural)	1,600 (planted)
Site 22 at 4 m						
Rotation-MAI	100-4.0	90-4.4	80-5.0	80-5.6	80-5.7	70-6.0
Average Dia (cm)	23	23	23	24	26	24
Av. Log/Med. Haul	149	271	414	532	687	604
Site 18 at 4 m						
Rotation-MAI	110-2.4	100-3.0	90-3.4	80-3.8	90-3.9	70-3.9
Average Dia (cm)	17	17	18	19	22	21
Av. Log/Med. Haul	-21	24	63	146	206	219
Site 14 at 4 m						
Rotation-MAI	170-1.3	130-1.7	110-2.0	90-2.3	100-2.4	90-2.5
Average Dia (cm)	16	16	16	16	18	19
Av. Log/Med. Haul	-50	-42	-29	-5	20	45
Site 22 at 10 m						
Rotation-MAI	80-4.0	70-4.5	80-5.0	80-5.6		
Average Dia (cm)	20	19	23	24		
Av. Log/Med. Haul	304	381	565	640		
Site 18 at 10 m						
Rotation-MAI	110-2.4	120-3.0	100-3.4	80-3.8		
Average Dia (cm)	17	22	20	19		
Av. Log/Med. Haul	20	113	150	265		
Site 14 at 10 m						
Rotation-MAI				90-2.3		
Average Dia (cm)	n/a	n/a	n/a	16		
Av. Log/Med. Haul				49		

NORTHERN INTERIOR REGION - LODGEPOLE PINE

Regime	20,000 (repression)	10,000 (repression)	7,000 (natural)	5,000 (natural)
Site 22 at 17 m				
Rotation-MAI		70-4.5	80-5.0	70-5.6
Average Dia (cm)	n/a	19	23	22
Av. Log/Med. Haul		861	1100	1246
Site 18 at 17 m				
Rotation-MAI		120-3.0	100-3.4	80-3.8
Average Dia (cm)	n/a	22	20	19
Av. Log/Med. Haul		403	508	729
Site 14 at 17 m				
Rotation-MAI				90-2.3
Average Dia (cm)	n/a	n/a	n/a	16
Av. Log/Med. Haul				379

SOUTHERN INTERIOR REGION - DOUGLAS FIR

Regime	10,000 (natural)	7,000 (natural)	5,000 (natural)
Site 25 at 4 m			
Rotation-MAI	90-6.4	80-6.3	80-6.4
Average Dia (cm)	25	23	24
Av. Log/Med. Haul	674	1028	1152
Site 21 at 4 m			
Rotation-MAI	80-4.3	80-4.4	80-4.5
Average Dia (cm)	17	18	19
Av. Log/Med. Haul	343	432	482
Site 16 at 4 m			
Rotation-MAI	110-2.6	110-2.5	100-2.6
Average Dia (cm)	16	16	16
Av. Log/Med. Haul	-11	-11	37

SOUTHERN INTERIOR REGION - WHITE OR ENGELMANN SPRUCE

Regime	10,000 (natural)	7,000 (natural)	5,000 (natural)	1,600 (planted)
Site 21 at 4 m				
Rotation-MAI	100-5.2	100-5.3	90-5.1	70-5.0
Average Dia (cm)	26	26	24	22
Av. Log/Med. Haul	516	526	533	597
Site 17 at 4 m				
Rotation-MAI	110-3.7	120-3.9	110-3.8	90-3.8
Average Dia (cm)	22	24	23	22
Av. Log/Med. Haul	130	141	177	270
Site 13 at 4 m				
Rotation-MAI	120-2.2	130-2.5	140-2.7	100-2.3
Average Dia (cm)	18	20	22	19
Av. Log/Med. Haul	-58	-50	-29	9

SOUTHERN INTERIOR REGION - LODGEPOLE PINE

Regime	20,000 (repression)	10,000 (repression)	7,000 (repression)*	5,000 (natural)	3,000 (natural)	1,600 (planted)
Site 22 at 4 m						
Rotation-MAI	100-4.0	90-4.4	80-5.0	80-5.6	80-5.7	70-6.0
Average Dia (cm)	23	23	23	24	26	24
Av. Log/Med. Haul	80	207	358	477	634	553
Site 18 at 4 m						
Rotation-MAI	100-2.3	90-2.9	80-3.3	100-3.8	70-3.6	70-3.9
Average Dia (cm)	16	17	17	22	19	21
Av. Log/Med. Haul	-94	-47	-7	75	122	151
Site 14 at 4 m						
Rotation-MAI	170-1.3	140-1.7	110-2.0	90-2.3	90-2.3	90-2.5
Average Dia (cm)	16	16	16	16	17	19
Av. Log/Med. Haul	-128	-121	-100	-69	-51	-32

SOUTHERN INTERIOR REGION - LODGEPOLE PINE

Regime	20,000 (repression)	10,000 (repression)	7,000 (natural)	5,000 (natural)
Site 22 at 10 m				
Rotation-MAI	80-4.0	90-4.6	80-5.0	80-5.6
Average Dia (cm)	20	22	23	24
Av. Log/Med. Haul	226	308	516	590
Site 18 at 10 m				
Rotation-MAI	100-2.3	120-3.0	80-3.3	80-3.8
Average Dia (cm)	16	22	17	19
Av. Log/Med. Haul	-46	44	84	189
Site 14 at 10 m				
Rotation-MAI				90-2.3
Average Dia (cm)	n/a	n/a	n/a	16
Av. Log/Med. Haul				-1
Site 22 at 17 m				
Rotation-MAI		70-4.5	80-5.0	70-5.6
Average Dia (cm)	n/a	19	23	22
Av. Log/Med. Haul		788	1079	1241
Site 18 at 17 m				
Rotation-MAI		90-2.9	80-3.3	80-3.8
Average Dia (cm)	n/a	17	17	19
Av. Log/Med. Haul		362	464	657
Site 14 at 17 m				
Rotation-MAI				90-2.3
Average Dia (cm)	n/a	n/a	n/a	16
Av. Log/Med. Haul				424

APPENDIX III

SPACING HEIGHT AND TOTAL AGE BY SPECIES, INITIAL DENSITY, AND SITE INDEX

Appendix 3 - Spacing height and total age by species, initial density and site index

COAST - DOUGLAS FIR

Regime	4,444 (natural)	2,500 (planted)	1,200 (planted)
	------ total age (years) when spaced ------		
Site 35 at 6 m	14	14	14
at 12 m	22	21	22
Site 30 at 6 m	16	16	16
at 12 m	24	24	25
Site 25 at 6 m	18	18	18
at 12 m	28	28	29

COAST - WESTERN HEMLOCK

Regime	10,000 (natural)	7,000 (natural)	5,000 (natural)	3,000 (natural)
	------ total age (years) when spaced ------			
Site 33 at 6 m	12	12	12	12
at 12 m	19	19	19	19
Site 28 at 6 m	14	14	14	14
at 12 m	23	23	23	23
Site 23 at 6 m	17	17	17	17
at 12 m	28	28	28	28

NORTHERN INTERIOR - HEMLOCK

Regime	10,000 (natural)	7,000 (natural)	5,000 (natural)
	------ total age (years) when spaced ------		
Site 20 at 6 m	19	19	19
Site 16 at 6 m	22	22	22
Site 12 at 6 m	28	28	28

NORTHERN INTERIOR - WHITE SPRUCE

Regime	10,000 (natural)	7,000 (natural)	5,000 (natural)	1,600 (planted)
	------ total age (years) when spaced ------			
Site 21 at 4 m	22	22	22	18
Site 17 aat 4 m	26	26	26	22
Site 13 at 4 m	32	32	32	28

NORTHERN INTERIOR - LODGEPOLE PINE

Regime	20,000 (repression)	10,000 (repression)	7,000 (repression)*	5,000 (natural)	3,000 (natural)	1,600 (planted)
	------ total age (years) when spaced ------					
Site 22 at 4 m	17	17	17	17	17	12
at 10 m	28	27	25	22	--	--
at 17 m	--	46	43	40	--	--
Site 18 at 4 m	18	18	18	18	18	13
at 10 m	37	35	32	30	--	--
at 17 m	--	63	58	53	--	--
Site 14 at 4 m	22	22	22	22	22	17
at 10 m	--	--	--	41	--	--
at 17 m	--	--	--	78	--	--

* repression only considered at 4 m

SOUTHERN INTERIOR - DOUGLAS FIR

Regime	10,000 (natural)	7,000 (natural)	5,000 (natural)
	------	total age (years) when spaced	------
Site 25 at 4 m	13	13	13
Site 21 at 4 m	15	15	15
Site 16 at 4 m	18	19	19

SOUTHERN INTERIOR - WHITE OR ENGELMANN SPRUCE

Regime	10,000 (natural)	7,000 (natural)	5,000 (natural)	1,600 (planted)
	------	total age (years) when spaced		------
Site 21 at 4 m	22	22	22	18
Site 17 at 4 m	26	26	26	22
Site 13 at 4 m	32	32	32	28

SOUTHERN INTERIOR - LODGEPOLE PINE

Regime	20,000 (repression)	10,000 (repression)	7,000 (repression)*	5,000 (natural)	3,000 (natural)	1,600 (planted)
	------	total age (years) when spaced		------		
Site 22 at 4 m	17	17	17	17	17	12
at 10 m	28	27	25	22	--	--
at 17 m	--	46	43	40	--	--
Site 18 at 4 m	18	18	18	18	18	13
at 10 m	37	35	32	30	--	--
at 17 m	--	63	58	53	--	--
Site 14 at 4 m	22	22	22	22	22	17
at 10 m	--	--	--	41	--	--
at 17 m	--	--	--	78	--	--

* repression only considered at 4 m

APPENDIX IV

DISCOUNTED NET REVENUE CALCULATION PROCEDURE AND FILES

Appendix 4. Discounted net revenue calculation procedure and files

Discounted net revenue calculation procedure

	Now (1992)		Future (End of Rotation)
1.	Operational volume Priced by diameter---->	1% real price increase large logs, no inflation--->	Future Product Revenue
2.	Logging Cost---------->	real, no inflation--------->	Deduct logging cost
	Hauling Cost---------->	real, no inflation--------->	Deduct hauling cost
3.	Annual carrying cost-->	at 4% cpd. interest--------> (annuity-future value)	Deduct carrying costs
4.	Treatment Cost (omitted at this stage, see 6. below)		
5.	Discounted Net Revenue (not including treatment cost) <----------	discount at 4% <----------	Future Net Revenue
6.	Now Value of Investment (net of treatment cost)	= DNR - Treatment Cost	

B.C. COAST

WOOD VALUES (1986-90)

DIA	D.F.	HEML	RPI FACTOR (%)
24	46.50	50.40	0
25	48.00	51.60	0
26	49.50	52.80	0
27	51.15	54.04	0
28	52.80	55.28	0
29	54.45	56.51	0
30	56.10	57.75	0
31	57.75	58.58	0
32	59.40	59.40	0.00110
33	61.05	60.23	0.00165
34	62.70	61.05	0.00220
35	63.53	61.88	0.00275
36	64.35	62.70	0.00330
37	65.18	63.53	0.00385
38	66.00	64.35	0.00440
39	67.24	65.18	0.00495
40	68.48	66.00	0.00550
41	68.89	66.41	0.00605
42	69.30	66.83	0.00660
43	69.71	67.03	0.00715
44	70.13	67.24	0.00770
45	70.54	67.44	0.00825
46	70.95	67.65	0.00880
47	71.57	67.86	0.00935
48	72.19	68.06	0.00990
49	72.81	68.27	0.00990
50	73.43	68.48	0.00990
51	74.25	68.89	0.00990
52	75.08	69.30	0.00990
53	75.90	69.71	0.00990
54	76.73	70.13	0.00990
55	77.55	70.54	0.00990
56	78.38	70.95	0.00990
57	79.61	71.57	0.00990
58	80.85	72.19	0.00990
59	82.50	72.81	0.00990
60	84.15	73.43	0.00990
61	84.97	73.85	0.00990
62	84.97	74.27	0.00990
63	85.80	74.68	0.00990
64	86.20	74.90	0.00990
65	86.60	75.10	0.00990

COAST LOGGING COST

	(D.F.)			(HEMLOCK)		
DIA	EASY	AVG	DIFF	EASY	AVG	DIFF
24	29.60	30.60	33.60	29.10	29.60	33.60
25	29.30	30.30	33.30	28.80	29.30	33.30
26	29.00	30.00	33.00	28.50	29.00	33.00
27	28.75	29.75	32.75	28.25	28.75	32.75
28	28.50	29.50	32.50	28.00	28.50	32.50
29	28.25	29.25	32.25	27.75	28.25	32.25
30	28.00	29.00	32.00	27.50	28.00	32.00
31	27.75	28.75	31.75	27.25	27.75	31.75
32	27.50	28.50	31.50	27.00	27.50	31.50
33	27.25	28.38	31.38	26.75	27.25	31.25
34	27.00	28.25	31.25	26.50	27.00	31.00
35	26.88	28.00	31.00	26.38	26.75	30.75
36	26.75	27.75	30.75	26.25	26.50	30.50
37	26.63	27.63	30.63	26.05	26.38	30.25
38	26.50	27.50	30.50	25.85	26.25	30.00
39	26.25	27.25	30.25	25.68	26.13	29.75
40	26.00	27.00	30.00	25.50	26.00	29.50
41	25.75	26.75	29.50	25.33	25.80	29.25
42	25.50	26.50	29.00	25.15	25.60	29.00
43	25.38	26.38	28.63	24.95	25.43	28.80
44	25.25	26.25	28.25	24.75	25.25	28.60
45	25.00	26.00	28.00	24.63	25.13	28.43
46	24.75	25.75	27.75	24.50	25.00	28.25
47	24.63	25.63	27.63	24.38	24.88	28.00
48	24.50	25.50	27.50	24.25	24.75	27.75
49	24.25	25.25	27.25	24.13	24.63	27.50
50	24.00	25.00	27.00	24.00	24.50	27.25
51	23.88	24.88	26.88	23.88	24.33	27.13
52	23.75	24.75	26.75	23.75	24.15	27.00
53	23.63	24.63	26.63	23.50	23.95	26.88
54	23.50	24.50	26.50	23.25	23.75	26.75
55	23.38	24.38	26.38	23.13	23.63	26.50
56	23.25	24.25	26.25	23.00	23.50	26.25
57	23.13	24.13	26.13	22.88	23.38	26.13
58	23.00	24.00	26.00	22.75	23.25	26.00
59	22.88	23.88	25.88	22.63	23.13	25.88
60	22.75	23.75	25.75	22.50	23.00	25.75
61	22.67	23.67	25.67	22.42	22.92	25.67
62	22.59	23.59	25.59	22.34	22.84	25.59
63	22.51	23.51	25.51	22.26	22.76	25.51
64	22.47	23.47	25.47	22.22	22.72	25.47
65	22.43	23.43	25.43	22.18	22.68	25.43

NORTHERN INTERIOR
WOOD VALUES (1986-90)

DIA	W. spruce	Pine	Hem/bal	RPI FACTOR (%)
16	37.35	32.88	36.58	0
17	38.10	33.56	37.26	0
18	38.85	34.23	37.93	0
19	39.32	34.69	38.16	0
20	39.78	35.15	38.39	0
21	40.24	35.38	38.62	0
22	40.70	35.61	38.85	0.0010
23	40.93	35.85	39.32	0.0015
24	41.16	36.08	39.78	0.0020
25	41.63	36.31	40.24	0.0025
26	42.09	36.54	40.70	0.0030
27	42.55	36.77	41.17	0.0035
28	43.01	37.00	41.63	0.0040
29	43.48	37.47	42.09	0.0045
30	43.94	37.93	42.55	0.0050
31	44.40	38.92	43.02	0.0055
32	44.86	39.91	43.48	0.0060
33	45.33	40.31	43.94	0.0068
34	45.79	40.70	44.40	0.0075
35	46.25	42.09	44.87	0.0083
36	46.71	43.48	45.33	0.0090
37	47.41	43.94	46.02	0.0095
38	48.10	44.40	46.71	0.0100
39	48.80	44.87	47.41	0.0100
40	49.49	45.33	48.10	0.0100
41	50.19	45.80	48.57	0.0100
42	50.88	46.26	49.03	0.0100
43	51.34	46.63	49.49	0.0100
44	51.80	47.00	49.95	0.0100
45	52.27	47.33	50.42	0.0100
46	52.73	47.65	50.88	0.0100
47	53.19	0.00	51.34	0.0100
48	53.65	0.00	51.80	0.0100
49	54.12	0.00	52.27	0.0100
50	54.58	0.00	52.73	0.0100

NORTHERN INTERIOR LOGGING COST

	(W. spruce)			(Pine)			Hem/Bal		
DIA	EASY	AVG	DIFF	EASY	AVG	DIFF	EASY	AVG	DIFF
16	23.15	23.50	24.75	21.40	21.75	23.00	25.15	25.50	26.75
17	22.15	22.50	23.75	20.53	20.88	22.13	23.90	24.25	25.50
18	21.15	21.50	22.75	19.65	20.00	21.25	22.65	23.00	24.25
19	20.40	20.75	22.00	19.03	19.38	20.63	21.65	22.00	23.25
20	19.65	20.00	21.25	18.40	18.75	20.00	20.65	21.00	22.25
21	19.15	19.50	20.75	18.03	18.38	19.63	19.78	20.13	21.38
22	18.65	19.00	20.25	17.65	18.00	19.25	18.90	19.25	20.50
23	18.40	18.75	20.00	17.40	17.75	19.00	18.65	19.00	20.25
24	18.15	18.50	19.75	17.15	17.50	18.75	18.40	18.75	20.00
25	17.78	18.13	19.38	16.90	17.25	18.50	18.03	18.38	19.63
26	17.40	17.75	19.00	16.65	17.00	18.25	17.65	18.00	19.25
27	17.15	17.50	18.75	16.40	16.75	18.00	17.40	17.75	19.00
28	16.90	17.25	18.50	16.15	16.50	17.75	17.15	17.50	18.75
29	16.65	17.00	18.25	15.90	16.25	17.50	16.66	17.25	18.50
30	16.40	16.75	18.00	15.65	16.00	17.25	16.16	17.00	18.25
31	16.15	16.50	17.75	15.53	15.88	17.13	16.16	16.75	18.00
32	15.90	16.25	17.50	15.40	15.75	17.00	16.15	16.50	17.75
33	15.65	16.00	17.25	15.28	15.63	16.88	15.90	16.25	17.50
34	15.40	15.75	17.00	15.15	15.50	16.75	15.65	16.00	17.25
35	15.15	15.50	16.75	14.90	15.25	16.50	15.40	15.75	17.00
36	14.90	15.25	16.50	14.65	15.00	16.25	15.15	15.50	16.75
37	14.65	15.00	16.25	14.40	14.75	16.00	14.90	15.25	16.50
38	14.40	14.75	16.00	14.15	14.50	15.75	14.65	15.00	16.25
39	14.15	14.50	15.75	13.90	14.25	15.50	14.15	14.50	15.75
40	13.90	14.25	15.50	13.65	14.00	15.25	13.65	14.00	15.25
41	13.65	14.00	15.25	13.40	13.75	15.00	13.40	13.75	15.00
42	13.40	13.75	15.00	13.15	13.50	14.75	13.15	13.50	14.75
43	13.28	13.63	14.88	12.90	13.25	14.50	12.90	13.25	14.50
44	13.15	13.50	14.75	12.65	13.00	14.25	12.65	13.00	14.25
45	12.90	13.25	14.50	12.40	12.75	14.00	12.53	12.88	14.13
46	12.65	13.00	14.25	12.15	12.50	13.75	12.40	12.75	14.00
47	12.40	12.75	14.00	0.00	0.00	0.00	12.28	12.63	13.88
48	12.15	12.50	13.75	0.00	0.00	0.00	12.15	12.50	13.75
49	12.03	12.38	13.63	0.00	0.00	0.00	11.90	12.25	13.50
50	11.90	12.25	13.50	0.00	0.00	0.00	11.65	12.00	13.25

SOUTHERN INTERIOR

WOOD VALUES (1986-90)

DIA	E.SPR	PINE	D.F.	RPI FACTOR (%)
16	35.79	32.21	45.00	0
17	36.47	32.89	46.67	0
18	37.14	33.56	48.33	0
19	37.81	34.23	49.23	0
20	38.49	34.91	50.12	0
21	39.16	35.58	50.79	0
22	39.83	36.25	51.46	0.0010
23	40.05	36.48	52.13	0.0015
24	40.28	36.70	52.81	0.0020
25	40.50	36.92	53.48	0.0025
26	40.72	37.14	54.15	0.0030
27	40.95	37.37	54.82	0.0035
28	41.17	37.59	55.49	0.0040
29	41.62	38.04	56.16	0.0045
30	42.07	38.49	56.83	0.0050
31	42.51	38.94	57.50	0.0055
32	42.96	39.38	58.18	0.0060
33	43.86	39.83	59.07	0.0068
34	44.75	40.28	59.97	0.0075
35	45.65	40.73	60.86	0.0083
36	46.54	41.17	61.76	0.0090
37	47.44	41.62	62.65	0.0095
38	48.33	42.07	63.55	0.0100
39	49.23	42.52	64.44	0.0100
40	50.12	42.96	65.34	0.0100
41	50.57	43.36	66.01	0.0100
42	51.02	43.75	66.68	0.0100
43	51.46	44.12	67.35	0.0100
44	51.91	44.50	68.02	0.0100
45	52.36	0.00	68.69	0.0100
46	52.81	0.00	69.36	0.0100
47	53.03	0.00	70.03	0.0100
48	53.25	0.00	70.71	0.0100
49	53.48	0.00	71.38	0.0100
50	53.70	0.00	72.05	0.0100

SOUTHERN INTERIOR LOGGING COST

	(E. spruce)			(Pine)			(D.F.)		
DIA	EASY	AVG	DIFF	EASY	AVG	DIFF	EASY	AVG	DIFF
16	24.20	24.50	25.90	21.95	22.25	23.65	23.70	24.00	25.25
17	23.20	23.50	24.90	21.45	21.75	23.15	22.70	23.00	24.25
18	22.20	22.50	23.90	20.95	21.25	22.65	21.70	22.00	23.25
19	21.45	21.75	23.15	20.58	20.88	22.28	21.08	21.38	22.63
20	20.70	21.00	22.40	20.20	20.50	21.90	20.45	20.75	22.00
21	20.18	20.50	21.90	19.93	20.25	21.65	20.08	20.38	21.63
22	19.65	20.00	21.40	19.65	20.00	21.40	19.70	20.00	21.25
23	19.40	19.75	21.15	19.40	19.75	21.15	19.58	19.88	21.13
24	19.15	19.50	20.90	19.15	19.50	20.90	19.45	19.75	21.00
25	18.90	19.25	20.65	18.90	19.25	20.65	19.20	19.50	20.75
26	18.65	19.00	20.40	18.65	19.00	20.40	18.95	19.25	20.50
27	18.53	18.88	20.28	18.40	18.75	20.15	18.83	19.13	20.38
28	18.40	18.75	20.15	18.15	18.50	19.90	18.70	19.00	20.25
29	18.15	18.50	19.90	18.03	18.38	19.78	18.30	18.63	19.88
30	17.90	18.25	19.65	17.90	18.25	19.65	17.90	18.25	19.50
31	17.65	18.00	19.40	17.65	18.00	19.40	17.53	17.88	19.13
32	17.40	17.75	19.15	17.40	17.75	19.15	17.15	17.50	18.75
33	17.15	17.50	18.90	17.28	17.63	19.03	16.90	17.25	18.50
34	16.90	17.25	18.65	17.15	17.50	18.90	16.65	17.00	18.25
35	16.53	16.88	18.28	16.90	17.25	18.65	16.40	16.75	18.00
36	16.15	16.50	17.90	16.65	17.00	18.40	16.15	16.50	17.75
37	15.90	16.25	17.65	16.40	16.75	18.15	15.90	16.25	17.50
38	15.65	16.00	17.40	16.15	16.50	17.90	15.65	16.00	17.25
39	15.40	15.75	17.15	15.90	16.25	17.65	15.40	15.75	17.00
40	15.15	15.50	16.90	15.65	16.00	17.40	15.15	15.50	16.75
41	14.90	15.25	16.65	15.40	15.75	17.15	14.90	15.25	16.50
42	14.65	15.00	16.40	15.15	15.50	16.90	14.65	15.00	16.25
43	14.40	14.75	16.15	14.90	15.25	16.65	14.40	14.75	16.00
44	14.15	14.50	15.90	14.65	15.00	16.40	14.15	14.50	15.75
45	13.90	14.25	15.65	0.00	0.00	0.00	13.90	14.25	15.50
46	13.65	14.00	15.40	0.00	0.00	0.00	13.65	14.00	15.25
47	13.40	13.75	15.15	0.00	0.00	0.00	13.40	13.75	15.00
48	13.15	13.50	14.90	0.00	0.00	0.00	13.15	13.50	14.75
49	12.90	13.25	14.65	0.00	0.00	0.00	12.90	13.25	14.50
50	12.65	13.00	14.40	0.00	0.00	0.00	12.65	13.00	14.25

HAULING COSTS

COAST REGION:

Douglas Fir -	Short Haul (25 km)	$4.50
	Medium Haul (40 km)	5.25
	Long Haul (25 km + water tow)	7.00
Hemlock -	Short Haul (25 km)	4.50
	Medium Haul (40 km)	5.25
	Long Haul (25 km + water tow)	8.00

NORTHERN INTERIOR REGION:

White Spruce -	Short Haul (35 km)	$4.75
	Medium Haul (55 km)	6.00
	Long Haul (70 km)	7.20
Lodgepole Pine -	Short Haul (50 km)	6.00
	Medium Haul (85 km)	8.00
	Long Haul (125 km)	10.25
Hemlock -	Short Haul (40 km)	5.70
	Medium Haul (60 km)	7.00
	Long Haul (80 km)	8.25

SOUTHERN INTERIOR REGION:

Englemann Spruce -	Short Haul (35 km)	$4.75
	Medium Haul (55 km)	6.25
	Long Haul (75 km)	7.75
Lodgepole Pine -	Short Haul (35 km)	4.75
	Medium Haul (55 km)	6.25
	Long Haul (75 km)	7.75
Douglas Fir -	Short Haul (35 km)	4.75
	Medium Haul (55 km)	6.25
	Long Haul (75 km)	7.75

Ministry of Forests Annual Management Expenses for the Care and Maintenance of Forests on Productive Forest Land[1]

Type of Expense	Region Coast ($000)	N.Interior ($000)	S.Interior ($000)
Harvesting	12,414	12,159	18,416
Research	697	1,327	1,664
Forest Protection	1,409	5,034	7,659
Timber Management Planning	474	967	1,697
Inventory	1,775	3,171	2,525
Fire Fighting	2,166	8,087	8,930
Fire Preparedness	1,976	4,560	5,803
Small Business	9,045	10,887	11,636
Management Services	6,630	10,224	13,110
	36,586	56,416	72,340
Productive Forest Land (000 ha)	4,945	26,815	13,837
Annual $ cost per ha	$7.40	$2.10	$5.23

1. Ministry of Forests expenditures on forest management annually, but not including integrated and recreation resource management, investments in intensive silviculture, estimated new road construction and estimated fire suppression on non-productive forest land. Headquarters expenditures pro-rated and allocated to the three regions on the basis of hectares of productive forest land managed.

Source: Derived from data in the Annual Reports of the Ministry of Forests, 1988-98 and 1989-90, and the 1990 Economic and Statistical Review of the Ministry of Finance and Corporate Relations.

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